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A Larval Population Technique for the Winter Moth (*Operophtera brumata* (Linn.) (Lepidoptera: Geometridae))[1]

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The winter moth, *Operophtera brumata* (Linn.), was not known to occur in North America until 1949, when it was first reported from the south shore of Nova Scotia by Hawboldt and Cuming (2) and Smith (4). By that time this introduced species was well established. It is suspected that the winter moth in association with the fall cankerworm, *Alsophila pometaria* (Harr.), has been causing considerable defoliation of deciduous tree species in the region since the early 1930's (2). The habits and stages of the winter moth have been described briefly by Smith (5), who also has indicated the important differences between the winter moth and the fall cankerworm (4).

The Forest Insect Survey is following the annual extension and intensity of the infestations and studying the natural control factors. The latest distribution map was published in 1951 (3), and only minor changes in distribution have occurred since that time. Preliminary studies by Smith (4) and Cuming (1) have suggested that control by native species of parasites or disease organisms is negligible. The introduction of European species of parasites has therefore been commenced by the Unit of Biological Control.

Sound sampling techniques are required to study the population of the insect and the effects of native and introduced control factors. Ultimately, these techniques should extend to larvae on the foliage, cocoons in the forest floor, and eggs on the bark. Because of the relative ease of larval sampling, emphasis has first been placed on this aspect of the work, with the object of measuring annual changes in larval populations at permanent plots and parasite liberation points. Later, techniques will be developed for the other stages, as well as sequential techniques for rapid survey purposes.

Sampling for the winter moth in Europe has consisted largely of counting adults trapped in sticky bands on tree trunks. The developing of detailed sampling techniques for other stages of this insect has apparently received little attention.

Experimental sampling was done in a young stand of red oak, *Quercus borealis* Michx. f., near Bridgewater, Nova Scotia, in 1952 and 1953. The techniques and results to date are described in this paper.

Selection of Stands and Trees

The principal outbreak is restricted to a narrow margin of the southern coastal area, and is most severe in or adjacent to towns and villages. Because of their proximity to settlements, most of the stands have been heavily cut, and the trees are generally large, scattered residuals, or small second growth. In selecting trees for study, it was considered preferable to use the latter.

The winter moth feeds on a great many tree species (4). Red oak, which appears to be second only to apple as the preferred host, was chosen for all sampling. Dominants or co-dominants in the second growth stand were selected at random. These sample trees ranged in height from about 20 to 25 feet, and

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in D.B.H. from about 4 to 5 inches. There is evidence that they had been only lightly to moderately attacked prior to 1952. The defoliation of the trees at the time of sampling in early June averaged 45 per cent in 1952 and 77 per cent in 1953. However, it increased to 60 per cent and 85 per cent, respectively, by the end of the feeding period in late June.

Field Procedure

The larvae can be sampled conveniently when the majority are in the fourth instar. At this time, about the first and second weeks of June, all the larvae are on the foliage and the two species are easily separated. Mature larvae start dropping to pupate about the middle of June.

Records on the sample trees included D.B.H., height, and percentage of defoliation. As indicated above, it was necessary to return to the plot at the end of the feeding period, but before refoliation of the trees, for more complete defoliation estimates.

Collections were made by the use of pruning shears fitted to a 20-foot extension pole. Branch terminals were clipped and fell into a basket attached to the end of the pole. Winter moth larvae were dislodged only rarely during sampling. Cankerworm larvae, however, were dislodged more easily, and it was necessary to make a correction in their population count. Since only about one-half of the clipped branch was used for the larval count, cankerworm larvae were alternately assigned to the used and unused portions of the branch.

The work was planned so that either a leaf or leaf cluster could be used as the sampling unit. The leaf cluster includes all the leaves on one new shoot. The number of leaves per cluster varies considerably but averages about seven in the study area. After taking a branch tip from the tree, a leaf cluster was removed, and the number of larvae was recorded for each leaf. The relative proportions of the winter moth and the cankerworm are extremely variable within the region, but the former predominated in the sample plot. The proportion of winter moth larvae in the collections was about 92 per cent both years. For this reason, as well as similarity in feeding habits, the larval counts for the two species have been amalgamated in the analysis that follows. Supplementary records included length of shoot, leaf length to the petiole (when possible), and the percentage of each leaf destroyed.

In 1953 about 50 leaf clusters per man-day were collected and analysed. With increased experience and discontinuance of some of the less important measurements, it is believed that this can easily be doubled and perhaps tripled.

Inter- and Intra-tree Variability

The object of the larval sampling, as stated above, is to detect annual changes in absolute population at permanent plots or liberation points. Therefore the first step in establishing a sampling procedure is to find how the insect is distributed within the crown of the tree, and how variability within the tree compares with variability from tree to tree. In other words, where do the important sources of variance arise? This information will permit a more exact definition of the sampling universe, particularly as to whether the tree should be accepted as an important factor in the universe or whether the forest should be visualized as a universe of foliage without regard to the particular trees on which it occurs. If it proves that the tree must be accepted as an important source of variance, then it is necessary to find the most economical rationing of available man-hours as between number of samples per tree and number of sample trees per plot. Throughout the following analysis two sample units, the leaf cluster and leaf, are retained and their relative merits are discussed under a later heading.

In 1952, the larval population on four trees was analyzed in some detail. Each tree crown was divided into four equal vertical levels, designated A, B, C, and D from the top of the crown to the base. Each level was divided into four equal quadrants, N, E, S, and W, according to the four cardinal points of the compass. This provided for 16 sampling positions within each crown, AN, AE, AS, AW, etc. At each sampling position, four leaf clusters were collected and examined for larvae as described above. In 1953, four additional trees were treated in the same way as a check on the 1952 results.

The mean values for the four trees of each year were as follows:

	1952	1953
Insects per leaf cluster	2.46	3.47
Insects per leaf per cluster	0.35	0.50
Shoot length (mm.)	46.4	48.9
Defoliation (%)	45.0	77.6

Our main concern is with the two expressions of population—insects per leaf cluster and insects per leaf per cluster. Shoot length and leaf length were recorded in case they would be of use in reaching a decision as to the most useful sample unit. As a result of the severe defoliation, however, the data on leaf length are too incomplete to be included. Defoliation represents the loss of foliage that had occurred up to the time of sampling and was recorded simply as an additional check on the insect distribution in the crown as indicated by the population figures.

From inspection alone, there was clearly no significant variance associated with the four quadrants in either year of the study. This was not unexpected. Observations on winter moth defoliation, as well as larval population studies on other defoliators, have suggested no consistent quadrantal patterns. Therefore, by accepting the quadrants merely as additional sources of replication, the analysis of variance can be considerably simplified (Table I).

The following conclusions may be drawn:

TABLE I

Analysis of Variance Showing the 'F' Values for the Variance between Trees, between Levels Within Trees, and the Interaction between Trees and Levels.

		Source of variance		
		Trees	Levels	Interaction
Insects per leaf cluster	1952	14.11**	1.97	1.72
	1953	5.72**	0.23	0.34
Insects per leaf per cluster	1952	3.97*	0.80	0.68
	1953	11.32**	1.70	0.55
Leaves per cluster	1952	5.57**	0.13	1.32
	1953	4.12*	5.85**	1.02
Shoot length	1952	3.54*	0.59	0.65
	1953	13.70**	6.92**	0.99
Defoliation	1952		Incomplete data	
	1953	25.35**	0.61	2.75*

*Significant within 5 per cent level.
**Significant within 1 per cent level.

1. Whether the leaf cluster or the leaf is used as the sample unit, the inter-tree variance is the only significant variance. The universe for sampling should therefore be considered a universe of trees, and the problem one of finding population on the 'mean' tree. (This universe is restricted, in the present study, to trees of dominant and co-dominant crown classes.) As quadrantal and level variances are not significant, the samples from any quadrant or level will be representative of the whole tree. This simplifies the sampling procedure because it is much easier to collect samples from the lower levels of standing trees. Unlike the cankerworm, winter moth larvae are not very motile once they are established in their feeding sites; however, the foregoing conclusions on distribution within the tree may require checking if unusual weather conditions are experienced during the sampling period.

2. The number of leaves per cluster shows significant inter-tree variance in both years. In 1953, the variance between levels is also significant and results from a greater number of leaves per cluster in the top levels (A and B). The same is true of shoot length, and the trees sampled in 1953 had significantly longer shoots in the A and B levels.

3. In general, the defoliation data support the population results and show that the major source of variance is inter-tree. The significant interaction in 1953 is contributed by one tree that had slightly greater defoliation in the C and D levels. On the other hand, the single tree on which detailed defoliation figures were obtained in 1952 had greater defoliation in the A and B levels.

Required Sample Size

On the basis of the 1952 results, 20 trees were selected and tagged in 1953 to provide more adequate data on inter-tree variance and required sample size. As level variance is not significant, only the easily-reached D level was used. Twelve leaf clusters were examined from each tree by selecting three clusters from each quadrant. Quadrantal variance is not significant but the use of quadrants is a convenient means of randomizing the samples. An analysis of variance was made on the data from these 20 trees and by the use of variance components, required sample size for two different levels of accuracy was computed (Table II). This procedure, shown at the bottom of Table II, has already been demonstrated by Stark (6).

For most insects, required sample size may vary widely according to the population mean. For high winter moth populations, like those of 1953, the following conclusions are suggested:

1. The total number of leaf clusters to be examined on a plot is minimum when only one cluster is selected from each tree. There is little advantage, statistically, in using more than about 16 clusters per tree; more intense sampling within the tree does not make any worth-while reduction in the number of trees that must be sampled.

2. The best combination to use on a given plot will generally lie somewhere between these two extremes, depending upon such practical considerations as the availability and spacing of good sampling trees and the time lost in moving from tree to tree. Also, populations on numbered trees may prove to be correlated from year to year; that is, the trees with the highest populations one year may be highest again the next year. If this is so, the method of paired variates will have statistical advantages in detecting mean population changes on the plot, and this may make it worth while to secure fairly adequate samples from each tree.

TABLE II

Different Combinations of 'Leaf Clusters per Tree' and 'Number of Trees' that will provide Equal Reliability Within Predetermined Limits.

No. leaf clusters per tree (n)	S.E. = 10% of mean		S.E. = 5% of mean	
	No. trees (T)*	Total No. leaf clusters (nT)	No. trees (T)	Total No. leaf clusters (nT)
When the sample unit is the leaf cluster:				
1	57	57	229	229
4	17	68	68	272
8	10	80	41	328
12	8	96	32	384
16	7	112	28	448
20	6	120	25	500
24	6	144	23	552
When the sample unit is the leaf:				
1	48	48	202	202
4	14	56	60	240
8	9	72	36	288
12	7	84	28	336
16	6	96	24	384
20	5	100	22	440
24	5	120	21	504

*For arbitrary values of n, the following formula is solved for T:

$$S.E. = \sqrt{\frac{Ss^2 + nSt^2}{nT}}$$

where, S.E. (standard error) is set at the desired percentage of the mean

Ss^2 = mean square for samples (leaf clusters) within trees

$St^2 = \frac{(\text{mean square for trees}) - Ss^2}{n}$, i.e., mean square for trees expressed as a component of variance.

3. For the type of stand used in the 1952 and 1953 sampling, the selection of 12 leaf clusters per tree appeared to give maximum return for expended effort. At this intensity, 8 trees would establish a mean with a standard error of ± 10 per cent, and 32 trees would reduce the error to ± 5 per cent.

Choice of Sample Unit

On the basis of the preceding analysis (Tables I, II) certain conclusions may now be drawn affecting the choice of the leaf cluster or the leaf as the appropriate sample unit for future work:

1. The use of the leaf rather than the leaf cluster has a slight statistical advantage (Table II). As the leaf is the unit of food, this is to be expected. Population per leaf cluster includes the variability in both population per leaf and number of leaves per cluster. However, the statistical advantage is small and would scarcely compensate for the extra time required to count leaves and keep separate records on them.

2. The number of leaves per cluster varies in the same way as shoot length (Table I). Correlation analysis between these two factors on eight trees shows significant correlation for each tree, the coefficients ranging between 0.56 and

0.91. It seems probable, therefore, that number of leaves per cluster, like shoot length, is an expression of tree vigour. It may be expected to vary from year to year, and be reduced by repeated defoliation. A reduction in the number of leaves per shoot from one year to the next would be reflected in an *apparent* increase in population per leaf, but not in population per leaf cluster. For the purpose of measuring changes in absolute population, therefore, the leaf cluster has advantages over the leaf. Of course, the number of leaf clusters (or shoots) per tree may also be influenced by growing conditions and defoliation, and thus lack stability as a unit for the measurement of absolute population. Further data on this factor are required but it seems very probable that the leaf cluster will offer greater stability than the leaf.

3. For the above reasons, the leaf cluster appears to be a more satisfactory sample unit than the leaf for the purposes of the present study.

Frequency Distributions

The data obtained during this preliminary work are too limited to reveal the nature of the frequency distributions. However, they have served their purpose in indicating a practical approach to the measurement of annual larval populations on permanent sample plots. A series of plots will be established in 1954 in stands suffering different degrees of infestation, and the data obtained during the next few years should be sufficient to permit an analysis of the frequency distributions. This will make it possible to apply suitable transformations to the sampling results before analysis, and to work out a sequential technique for more general survey purposes.

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Needle-Mining Habits and Larval Instars of the Spruce Budworm[1]

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Introduction

Many of the early papers on the spruce budworm, *Choristoneura fumiferana* (Clem.), included accounts of the general habits and seasonal history of the insect (9, 13, 18, 19, 22). Later papers have been concerned principally with ecological or pathological relations, current infestations and damage, or chemical control. There has not been, however, any detailed account of the salient features of the development of the spruce budworm.

In 1946, the writer undertook a study of the development of the spruce budworm in northwestern Ontario. Certain phases of the investigation were continued until 1949. The field studies were carried out in the vicinity of Black Sturgeon Lake, 90 miles northeast of Port Arthur, where a severe outbreak of the budworm occurred during the decade 1940-50. Special emphasis was placed on the needle-mining habits of young larvae following emergence in the spring, and on the number and separation of larval instars. A thorough knowledge of these features is of especial value in studies dealing with population sampling, natural control factors, the timing of chemical control operations, and various ecologcal relationships. Observations and records were maintained on all developmental stages, but detailed treatment is not warranted. The salient features, however, are included in a brief review of the life history of the budworm which precedes a discussion of needle-mining habits and larval instars.

Life History of the Spruce Budworm

Eggs

Spruce budworm eggs are laid on the needles of the host tree as pale green clusters which are noticeably lighter in colour than the foliage. The eggs are arranged in rows which give a scale-like appearance to the egg masses when examined closely. The clusters occur on either side of balsam needles but the first eggs laid are always nearest the apex of the needle. The number of eggs in a cluster varies considerably; single eggs and clusters approaching 60 eggs have been noted. The average is approximately 20 eggs per cluster. Shortly before hatching the eggs darken in colour as pigmentation develops in the head capsule and other parts of the embryo. No apparent sequence in hatching was observed as described by Gibson (11). The egg shells remain attached to the needles for some time and bear evidence of the size of the mass, and the numbers hatched, unhatched, and parasitized. Their value in sampling procedures has been amply demonstrated (5, 17).

The number of eggs laid by individual females is quite variable and has been shown to vary with the degree of current defoliation (2). The average number of eggs laid per female in 1946, 1947, and 1948 in the present study was 111, 119, and 99 respectively. The average number of egg clusters deposited by a female was found to be approximately six with variations from one to as high as 27. The majority of females oviposited within 24 hours following mating but occasionally nearly a week elapsed before the first clusters were found. Oviposition is generally completed within 4 to 6 days; in one instance the period between mating and the last oviposition was 11 days.

The incubation period is quite variable under field conditions. Seasonal averages ranged from slightly less than 8 days to more than 12 days. When

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expressed in Developmental Units (4, 21) or degree-hours over 42°F., the incubation period was found to be reasonably constant at approximately 2400 units.

Larvae

The larval period begins in late July or early August of one year and continues through the winter months until late June of the succeeding year. Newly-hatched larvae hibernate in protected locations on the host tree and moult to the second instar shortly after completion of silken hibernacula. In early spring, second-instar larvae emerge and mine previous years' needles, feed on staminate cones, or enter compact vegetative buds. As soon as the vegetative buds begin to swell and expand, the larvae migrate to this source of succulent food where they complete their development in three to four weeks. Pupation takes place on the host tree.

Larval stadia are quite variable but two general trends are apparent. The fifth stadium is the shortest and the sixth the longest. Male larvae tend to develop more rapidly than females, particularly in the sixth stadium, resulting in the first pupae being invariably males.

Pupae

Spruce budworm pupae pass through their entire development on the host tree. Following a short prepupal period, a larva transforms into a characteristic obtect pupa (3). Typically this transformation takes place within the feeding shelter of the mature larva. Under certain conditions, however, pupae may be found anywhere on the host tree.

Well-advanced sixth-instar larvae of each sex collected from both white spruce and balsam fir trees were reared to obtain pupae for study. Pupae were formed in a very definite sequence reflecting observations outlined in the preceding sub-heading and the relative development on the two hosts. As development on white spruce was ahead of that on balsam fir, and males pupated earlier than females as a result of their shorter larval stadia, the sequence of pupation was from males on white spruce through to females on balsam fir.

The mean pupal periods for the two sexes were highly significantly different regardless of the host. As the mean differences between the same sex on the two hosts was approximately twice that between sexes, they must also be presumed to be significantly different. Generally speaking, the pupal period averaged approximately 8 or 9 days under field conditions with the difference between sexes on the same host being 5 hours and the difference between the same sex on the two hosts being 10 hours. Females from white spruce had the shortest pupal period and males from balsam fir the longest.

Adults

Most early writers on the life history and habits of the spruce budworm concerned themselves with brief descriptions of the moths and recording mass flights and early seasonal records. More recently, the moths have been described in detail (7, 8) and a number of authors reported on the effects of physical factors (24, 25), meteorological conditions causing mass flights (12), the role of mass flights in the initial stages of an infestation (9, 10), and the effects of complete defoliation on the fecundity and flight habits (2). Adult longevity has not been the subject of much investigation but was given some attention in the present study.

The longevity of 199 unmated adults, representing approximately equal numbers of each sex, and 42 mated pairs was observed. Since the number of adults was not large and the variation in longevity was considerable (2 to 20 days), no definite conclusions can be drawn. Generally speaking, however,

females lived longer than males under all conditions and unmated adults lived longer than mated ones.

Needle-Mining Habits

The mining of needles by the spruce budworm, before attacking the current year's growth, was given very little attention by early investigators. The only reference to this feeding habit published prior to 1940 is a general statement in a review article by Swaine (23). Atwood (1) was the first to describe, in any detail, the needle-mining habit from observations in the spring of 1941 and 1942 near Laniel, Quebec. He suggests that this type of feeding might be atypical, resulting from the exceptionally early spring in those years. It is now generally accepted, however, that the mining of needles is typical of the budworm in eastern Canada. It was observed by the writer each spring from 1945 to 1950 in northwestern Ontario. Weather and temperature conditions favourable for the emergence from hibernacula precede the swelling and bursting of vegetative buds and larvae resort to mining needles, or staminate cones when available, for food until such time as the buds burst. Rose and Blais (20) studied the relationship between spring temperatures and budworm emergence.

In mining a needle, a larva eats a small hole in the epidermis and feeds on the palisade and vascular tissues, avoiding the resin ducts. The cavity so formed becomes large enough to accommodate the larva and in this protected position feeding continues. A considerable amount of silk is spun outside the mine. This silk and the translucence of the mined portion make mined needles easily discernible.

Special emphasis was placed on the following features of the needle-mining period: the proportions of larvae that mine needles or enter compact buds directly; the average number of needles mined by a single larva; the average time spent in mining needles; the variations that occur among the host trees on which mines occur, namely, balsam fir, white spruce, and black spruce. Observations were made directly on larvae living under field conditions in an extensive stand of immature spruce and fir that followed a burn approximately 30 years earlier. The trees in this area supported a heavy infestation of the budworm from the early forties until 1949. The size of the trees and the open nature of the stand afforded an excellent site for direct observation of budworm activity. Quantitative observations were limited to balsam fir but general comparative observations were made periodically on black and white spruce trees.

Quantitative observations consisted of examining a series of selected branch tips at one- or two-day intervals. The same series of 22 branches with a few minor alterations was used in 1946, 1947 and 1949. In 1948, the writer was unable to be present at the initiation of field activities and a new series of 15 branches was selected by an assistant. These were in the same vicinity and in several instances on the same trees. At each examination, each branch was closely scrutinized for signs of insect activity. Mined needles and attacked buds were tagged and numbered. Records were kept of the dates mines were first observed, when they were vacated, and when buds were attacked. These records were maintained until all the mined needles were vacated and larvae were established in the elongating shoots. A small number of mined needles were lost due to wind or mechanical action. Some larvae died without leaving the mines. General notes were kept on weather conditions to allow rough correlations with the recorded insect activity.

The resultant data are presented graphically in Fig. 1. The three curves for each season represent the two-day summations of activity in terms of; (1)

number of new mines, (2) number of vacated mines, and (3) the number of newly attacked buds.

In 1946, when the most intensive studies on needle mining were carried out, the first activity was noted on May 13. The favourable weather conditions

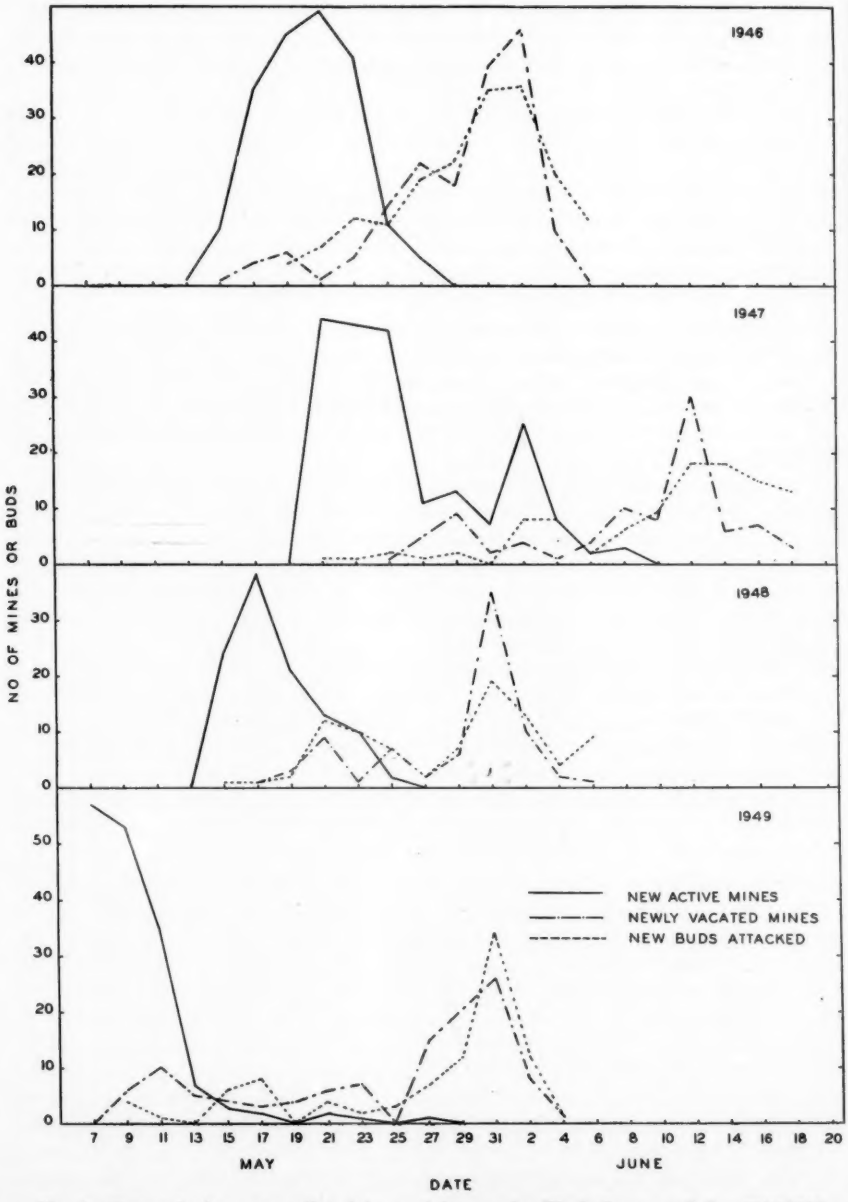

Fig. 1. Spruce budworm needle-mining activity graphs, Black Sturgeon Lake, 1946-1949.

that contributed to the gradual exodus of larvae from hibernation between May 13 and May 20 continued through the remainder of the needle-mining period. This resulted in very regular activity curves. The unimodal nature of the "new mine" curve and the close similarity between the "vacated mine" and "attacked bud" curves indicate that the great majority of larvae mined needles initially and that few, if any, mined more than one needle.

Six instances were noted where a new mine was formed close to a newly vacated and incompletely mined needle. Apparently the first needle attacked was in some way found unsatisfactory and a second needle was attacked. The late appearance of attacked buds indicated that relatively few larvae passed directly to buds without mining needles. It is probable that some larvae, late to emerge, attacked buds directly during the period May 19-23 where the "attacked bud" curve exceeds the "vacated mine" curve. There is a striking relationship between these two curves following this initial period. Their peaks represent the rapid migration of larvae from mines to buds as soon as the shoots began to develop.

In 1947, spring emergence was delayed until May 20-21. No activity was noted during a careful examination of foliage on May 19. An abrupt change in the weather resulted in a rapid emergence of larvae as evidenced by the numerous mined needles on May 21. The remaining period of needle-mining activity was characterized by widely fluctuating weather conditions of which the erratic nature of the activity curves bears evidence. A period of unfavourable weather was followed by a small rise in activity on May 26-27. The increase in new mines was coincident with an increase in vacated mines indicating that a number of larvae resorted to mining a second needle. The second, more definite peak on June 1 and 2 coincided with a substantial increase in the number of attacked buds and few vacated mines. This is thought to be a delayed resumption of emergence from hibernation as has been described by Rose and Blais (20). Some of these larvae undoubtedly went directly to buds which by this time were beginning to expand. The remaining portions of the graphs are quite comparable to those for 1946.

In 1948, budworm activity was first observed on May 13 in the vicinity of the tagged branches but it was not until May 15 that a number of new mines and one attacked bud were noted on the branches under observation. Very few larvae went directly to compact buds. During the period May 21-24, however, the last exodus of larvae from hibernation apparently distributed themselves almost equally between needles and buds. A short period of adverse weather limited activity during the period May 25-27. The very favourable weather conditions that prevailed late in May and the early days of June caused the characteristic mass migration of larvae from mines to elongating shoots. With the exception of the marked cessation of activity mentioned above, the conditions in 1948 closely paralleled those of 1946.

Unusually early emergence of larvae from hibernation occurred in 1949. Larvae had already emerged in considerable numbers when the study area was visited May 6. The following day, 57 new mines were noted on the tagged branches. It is estimated that emergence, in quantity, began on May 5. The activity graphs indicate that emergence was essentially complete by May 14 but that small numbers continued to emerge until about May 21. A period of unfavourable weather, May 19-25, nullified the influence of the early emergence. Following this period, there was a rapid migration of larvae to the elongating shoots and all mines were vacated by June 4 which coincided almost exactly with the same event in 1946 and 1947.

In Fig. 1 the activity graphs for all four years are presented on the same time scale to facilitate inter-year comparisons. The same basic pattern of activity occurred each year, irrespective of the time of inital emergence or the general weather conditions. Weather conditions exert a marked influence on the course of development, but not sufficiently to alter its essential features. It is possible, however, to distinguish two main variations. In 1946, 1948, and 1949, the results are very similar, except for the length of time between the two main peaks of activity. The 1946 conditions were very close to optimum, with 1948 and 1949 showing the effect of progressively longer periods of adverse weather following larval emergence. In 1947 needle-mining activity occurred later and was very erratic, reflecting the effects of a late slow spring with periods of widely fluctuating weather conditions.

Larval mortality during the needle-mining period can be estimated if the ratio of total mines to total buds attacked can be accepted as a rough index. The average time spent in a mine and the actual number of dead larvae found in mines, supply further supporting evidence. These figures are presented in Table I and show the effect of the prolonged period of adverse weather of 1949 and the erratic weather conditions in 1947.

TABLE I

Larval Mortality of the Spruce Budworm during the Needle-Mining Stage, Black Sturgeon Lake, 1946–1949.

Year	Ratio of needles mined to buds attacked	Av. length (days) of needle-mining period	Percentage of mines with dead larvae
1946	1:0.90	9.8	7.6
1947	1:0.53	13.4	24.7
1948	1:0.81	10.6	6.5
1949	1:0.58	14.6	9.3

The majority of mines occur in needles produced the previous year. Records were kept, except in 1948, of the age of all mined needles. The proportions of the mines formed in 1-year-old needles were: 98 per cent in 1946; 93 per cent in 1947; and 87 per cent in 1949. The apparent trend in these percentages may be correlated with the fact that the majority of mines in foliage older than one year occurred on the most heavily defoliated branches.

Although the number of larval instars and their development are dealt with in a later section, it is of interest to note what larval instars occur in needle mines. Larvae are in the second instar when they emerge in the spring and begin to mine needles. Collections were made at fairly regular intervals throughout the entire larval period. The first five collections were subdivided into two groups based on feeding site. One group consisted of larvae actually found in mines; the other larvae found in or on buds (Table II). Second- and third-instar larvae were present in both mines and buds. Larvae moult from the second to the third instar either before or after they leave the mines.

The above observations are based on detailed studies on balsam fir trees. General observations on black spruce and white spruce trees showed a number of significant variations.

TABLE II

Instar Composition of Spruce Budworm Larval Collections, Black Sturgeon Lake, 1946

Date of Collection	Instars found in Mines:		Instars found in buds:			Total
	2nd	3rd	2nd	3rd	4th	
May 23.....	58	–	–	–	–	58
May 28.....	16	8	17	10	–	51
May 31.....	9	33	13	45	–	100
June 3.....	2	9	3	86	–	100
June 5.....	–	1	–	53	22	76
Totals.....	85	51	33	194	22	385

On spruce trees, it was not uncommon to find groups of two to six mined needles in which usually only one larva could be found. Undoubtedly, the entire group of mined needles was the work of a single larva. This behaviour may result from spruce needles drying out quickly when mined. The entire needle turns a pale green shortly after the mining begins. The dried needles apparently do not afford suitable food and a larva soon migrates to a new needle nearby. The groups of partially mined needles are the result. Balsam fir needles, on the other hand, do not appear to dry out in this manner as the uneaten portion remains a normal green colour even long after the mine has been vacated.

Sections of spruce and balsam needles, mined and unmined, did not disclose any anatomical or feeding differences that might account for the different reactions. In fact, the double nature of the epidermis of spruce needles should result in a greater resistance to desiccation. Apparently the abscission layer of spruce needles is stimulated by the mining injury. This explanation would account for the fact that the mined spruce needles are so easily dislodged.

The needle-mining period on black spruce is considerably longer than on white spruce and balsam fir because of the later opening of the buds. White spruce buds open as soon as, or slightly earlier than, balsam fir buds and shoot elongation is very rapid. This early source of succulent food in quantity probably accounts for larvae on white spruce developing slightly ahead of larvae on balsam fir throughout the larval period.

Larval Instars and Their Separation

The number of larval instars in the spruce budworm has been the subject of debate. Most early writers stated that there were six larval instars but presented little experimental evidence. Mathers (16) concluded from head-width measurements of field-collected larvae that there were six instars in the two-year-cycle form of the spruce budworm in certain parts of British Columbia. General field observations have led some workers to think that the spruce budworm in eastern Canada possibly passes through more than six instars. Lejeune (14) gave evidence of seven instars in the closely related jack-pine budworm (*Choristoneura pinus* Free.) in northwestern Ontario and Manitoba.

One of the main purposes of the present study was to establish the characteristic number of larval instars and any variations therefrom for the spruce budworm

in eastern Canada. Two approaches were made to this problem during 1946 and 1947. Larvae were reared individually and the cast head capsules collected. At the same time, field-collected larvae were preserved for measurement and study.

The preserved material was collected from balsam fir trees at two- or three-day intervals throughout the entire larval period. The maximum head width was measured for up to 100 larvae from each collection. Since first-instar larvae are present only in the late summer, 110 larvae were preserved immediately upon hatching from eggs in August. A frequency distribution of all the resultant head widths was prepared (Fig. 2). The sexing of larvae by external evidence of male gonads was precise enough for the last two instars to allow the data to be subdivided on the basis of sex.

The reared larvae were collected as soon as possible after emergence in the spring; the majority were in the process of mining a needle. The larvae were reared individually and examined daily. All head capsules were retained and measured. The sex of all individuals reaching the pupal or adult stage could be readily determined; individuals not reaching these stages were sexed in the same fashion as the preserved larvae. In 1946, 123 larvae were reared. The high mortality of small larvae necessitated the collection of 40 additional larvae at a time when many had already moulted once. The parasite, *Apanteles fumiferanae* Vier., killed 26 of the larvae. In 1947, 120 larvae were reared individually and only one case of parasitism by *Glypta fumiferanae* (Vier.) was recorded. None of the larvae in either year moulted more than four times during the feeding period. These moults and that which occurs in the hibernaculum indicate six larval instars. This is in agreement with the results of the head-capsule measurements (Fig. 2) where six distinct peaks are evident. The only inconsistencies in the rearing data were three larvae reared in 1946. They were among a group of 13 larvae that were 5 to 7 days later than the majority in moulting for the first time. Of this group, five were parasitized and one died after the first moult. Of the remaining seven, four produced adults (two males and two females) after the normal complement of moults, and three produced adults (two females and one male) after evidently eliding one instar. They cast a normal-sized third-instar head capsule and then, after the time usually required for only one stadium, a head capsule of the size usually associated with a fifth instar was moulted. Evidently these three individuals elided the fourth instar. The above results make it very unlikely that spruce budworm larvae have more than six larval instars under field conditions.

Although knowledge of the number of larval instars is fundamental, it lacks practical application unless the instars can be distinguished. Instar recognition would be of value in any studies where specific information on the seasonal development of populations is required. There have been no descriptions published of all larval stages. Writers (9, 18, 22) have focussed their attention on the early and late stages omitting the troublesome third and fourth instars. The most recent descriptions are those of MacKay (15) who treated the second and sixth instars in detail in comparisons with similar stages of the jack-pine budworm. The absence of descriptions in the literature and differing opinions on the number of stages are evidence of the difficulties to be expected in attempting a separation of all stages. Nevertheless, it was hoped that a careful study of the morphology of larvae of known instar might disclose criteria for definitely separating the instars.

Head-Capsule Size

As head-capsule size remains constant during an instar and its increase in size, from instar to instar, is an index of larval growth, it should be an excellent diagnostic feature. Its value can be assessed through examination of Fig. 2 and

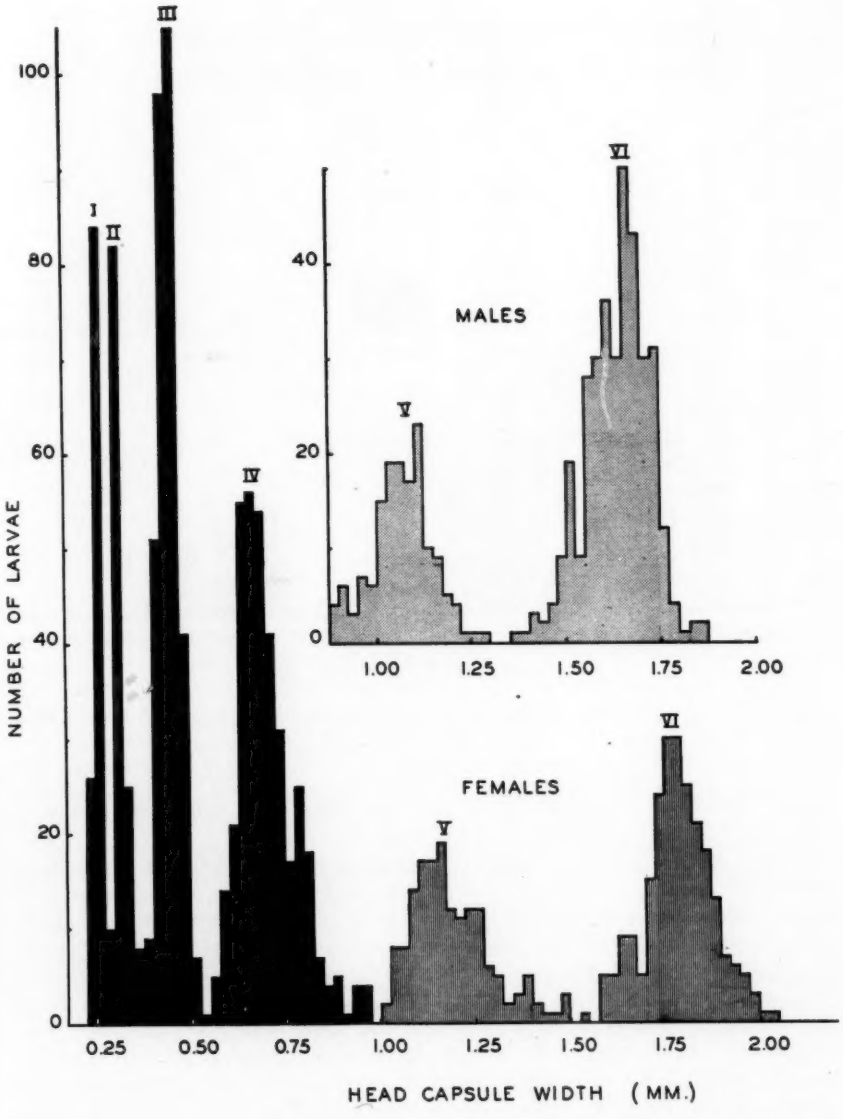

Fig. 2. Spruce budworm head-capsule widths derived from periodic preserved collections, Black Sturgeon Lake, 1946.

Fig. 3. The latter presents the head-capsule measurements of the larvae reared individually in 1946. In this figure, the sixth instar is missing as larvae were allowed to pupate, the head capsule being split in the process. In Fig. 2 each instar has a well-defined peak. The extremes of each instar, however, merge with those of the adjacent instars. In the great majority of cases, the head-

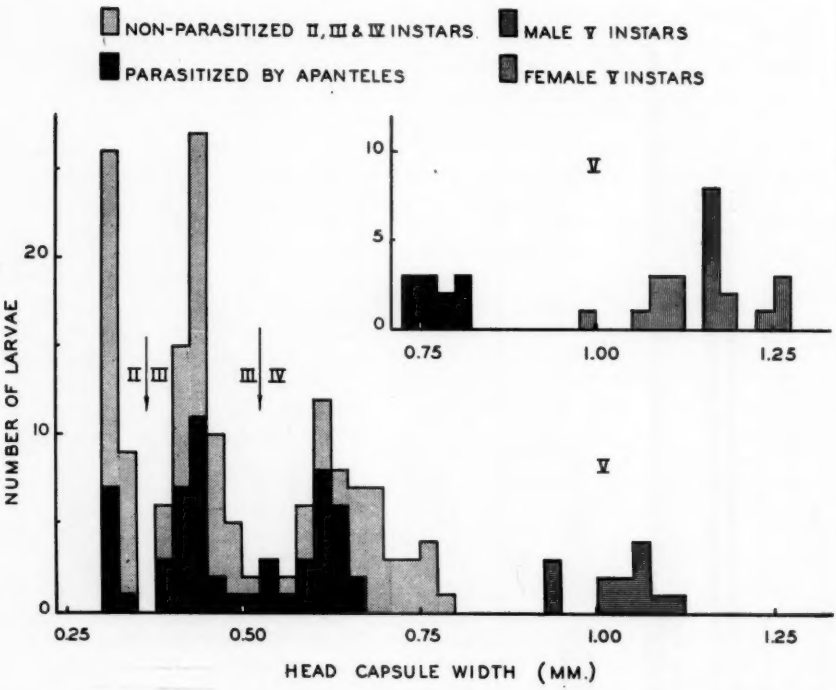

Fig. 3. Spruce budworm head-capsule widths derived from individual rearings, Black Sturgeon Lake, 1946.

capsule width would definitely establish the instar but borderline cases occur that could only be resolved by resorting to other criteria.

Two factors have been found to contribute to the variation in head-capsule size within an instar: namely, sex differences and the effects of parasitism. The sex differences are apparent in Fig. 2 and the statistical evidence of their significance appears in Table III. The mean head-capsule widths of male fifth- and sixth-instar larvae are distinctly smaller than those of females. As no attempt was made to sex fourth-instar larvae, any difference that may occur can not be demonstrated. It should be recalled that the sexing was based on the external evidence of male gonads. As will be discussed in a later paper, this technique does not result in a completely accurate separation of the sexes; some male larvae being included with the females. Inaccuracies in this direction, however, would tend to nullify rather than accentuate the demonstrated differences. This sex difference, which becomes more pronounced in the later instars, increases the range of head-capsule size within the later instars and complicates the use of head width as a means of separating instars.

The striking influence of parasitism on head-capsule size is shown in Fig. 3. The data are from individual rearings where the instar was known regardless of the size of the head capsule. In the figure, head capsules of larvae parasitized by *Apanteles fumiferanae* (Vier). are distinguished from those of unparasitized larvae. In every instar, the head capsules of parasitized larvae tend to be located near the

TABLE III

Mean Head Width and Associated Data for Spruce Budworm Larval Instars
(based on measurement of preserved larvae—1946)

Instar	N	Mean head width (mm.)	Standard error (mm.)	Mean difference (mm.)	Value of "t"
First	110	0.252	0.0012		
Second	117	0.314	0.0013		
Third	318	0.445	0.0017		
Fourth	348	0.682	0.0035		
Fifth					
Male	150	1.06	0.0065	0.09±0.010	18.0**
Female	154	1.15	0.0076		
Sixth					
Male	348	1.63	0.0044	0.16±0.0073	50.2**
Female	232	1.79	0.0059		
	1,777				

lower limits for that instar. This is particularly true for the fourth and fifth instars where the range of head-capsule size is greater. The most outstanding example is in the fifth instar where the head capsules of the parasitized larvae form a distinct group. *Apanteles* larvae usually emerge from the fourth instar of the host, but occasionally the host larva moults just prior to the emergence of the parasite. If this occurs, the head capsule of the resultant fifth-instar host larva is only slightly larger than the fourth-instar capsule. The increments in parasitized larvae varied from 0.025 to 0.225 mm. while the average increment between these instars was in excess of 0.4 mm.

In conclusion, head-capsule width is a good diagnostic feature in separating larval instars of the spruce budworm but its value is somewhat limited by the progressively increased variability within an instar introduced by sex differences and the influence of certain parasites.

Setal Pattern

The setal pattern of first-instar larvae is usually more generalized and differs from succeeding instars. Although the definitive pattern is usually assumed after the first moult, the possibility of minor differences that would allow the separation of at least some of the instars was investigated.

No significant differences were found in the chaetotaxy of the head capsule of any of the instars. The only variation noted, other than size, did not concern the setae. In the sixth instar, lines, where splitting will occur to allow the pupa to escape, are plainly visible in cleared specimens. They run almost parallel to and slightly laterad of the adfrontal sutures.

In order to study setation of the body segments, larvae of each instar were prepared as follows: The body contents were rolled out between blotting papers. A narrow edge of the flattened body wall was trimmed off. The remainder was flattened out as a single layer and mounted in glycerine for microscopic examination after soaking in warm sodium hydroxide had removed any tissue clinging to the cuticula. Setal maps were prepared for each instar but owing to their simi-

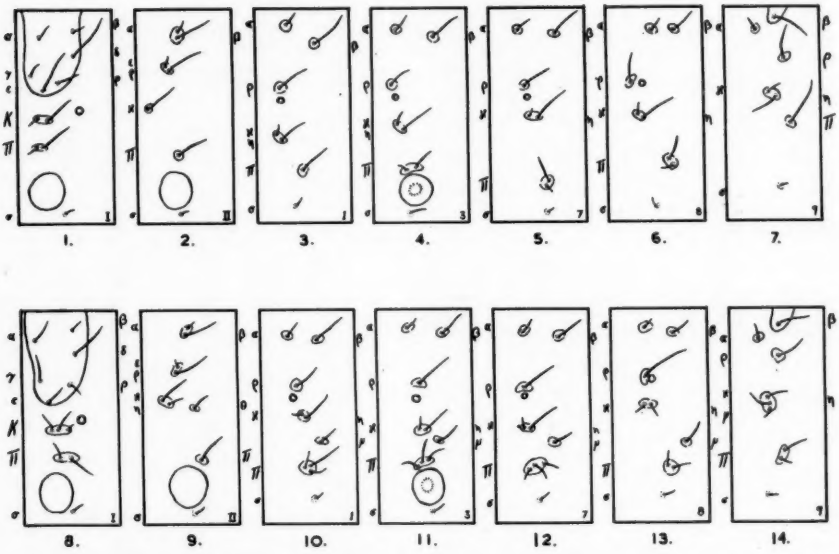

Fig. 4. Setal maps for spruce budworm larvae: Nos. 1-7 first instar; Nos. 8-14 sixth instar. Body segments are indicated in the lower right-hand corner of each map.

larity only the first and sixth instars are presented (Fig. 4). In these illustrations, the nomenclature of Fracker (6) is followed.

As the definitive pattern was completely assumed after the first moult, the diagnostic value of the setal pattern is limited to a separation of the first two instars. This is of little consequence as the first instar is very inconspicuous and only present for a short period in the late summer. The differences between the first and second instars are in complete accord with the theories of Fracker (6). The following are the differences noted: (1) The Kappa group of the prothorax is bisetose in the first instar and adds a subprimary, theta, in the second instar. (2) Theta and eta, another subprimary, do not make their appearance on the meso- and metathoracic segments until the second instar. (3) Mu, a subprimary found only on the abdomen of Frenatae, is not present on any of the abdominal segments until the second instar. (4) The variable Tau group, which occurs in conjunction with pi to form the Pi group, is completely absent from the first two is composed of two setae in all but the eighth and ninth segments of the second instar.

Colour and Sclerotization

The intensity of coloration in the head capsule, thoracic legs, and prothoracic shield of spruce budworm larvae seems to be correlated with the degree of sclerotization and varies from instar to instar. Other parts of the cuticula, although not heavily sclerotized, also undergo certain colour changes which are described below.

The general body colour of newly hatched larvae is a pale greenish-yellow which is reminiscent of the colour of eggs and probably due to an accumulation of yolk material in the digestive tract. This colour is lost very soon. The second instar larva, while over-wintering and when it emerges in the spring, is a light orange colour. This lightens as the larva feeds until the typical cream colour of

immature spruce budworm larvae is reached. Within each instar there is a progressive lightening of colour as the body wall distends to its maximum size.

In the sixth instar a distinctive colour pattern is assumed. When freshly moulted, the dorsum of the body is dark chocolate-brown punctuated with button-like, cream-coloured, piliferous tubercles. The venter is a similar but lighter brown. The stigmatal band remains the cream colour typical of the previous instars. As feeding progresses, the dark brown dorsum lightens in colour but the stigmatal band remains conspicuous. As the fully-fed condition is approached, larvae often assume a general greenish cast from the colour of the body fluids and the contents of the digestive tract.

The progressive darkening of such heavily sclerotized areas as the head capsule, thoracic legs, and the prothoracic shield are of some value in distinguishing larval instars. In the first instar, the head capsule is a light amber colour and is translucent under strong light. The prothoracic shield and thoracic legs are the same colour as the body. The head capsule of the second-instar larva is slightly darker and only barely translucent. The prothoracic shield and the legs, particularly the pretarsus, are noticeably darker than the body.

By the third instar the head capsule is dark brown in colour. The prothoracic shield is quite evident but lighter than the head capsule. The thoracic legs are a deep amber colour in their entirety. There is a further intensification of colour in the fourth instar, particularly of the thoracic legs. The prothoracic shield is still lighter than the head capsule.

In the fifth instar, the head and prothoracic shield are concolorous, dark brown or black. There is an inconspicuous median line on the prothoracic shield. The legs are also dark brown or black. In the last instar, the head capsule and legs remain dark brown or black but there is a decrease in the pigmentation along the anterior margin and the median line of the prothoracic shield.

The colour differences outlined above vary somewhat in different individuals. Thus, their greatest value lies in supplementing and confirming instar identifications based on other criteria.

Prolegs

Considerable use has been made of prolegs in the description and classification of lepidopterous larvae. In the spruce budworm, they are rather primitive, the crochets being unseriate and in a complete circle. The number of hooks or crochets, which varies with instar, was counted on nearly 500 prolegs representing 126 larvae (Table IV). Only those amenable to accurate counting were used and anal prolegs were disregarded. In addition to the quantitative differences, it was noted that the crochets are distinctly uniordinal in the first three instars. In the last three instars, there is a gradual trend toward the biordinal condition of the sixth instar.

The larvae upon which Table IV is based were selected to give representation to each instar. There was no selection as to sex or possible parasitism. The table shows the variation in the number of crochets per proleg within a particular instar. There is also appreciable variation among the prolegs of an individual larva. The absolute instar ranges show considerable overlapping, which is reduced somewhat if larval averages are substituted. In the later instars, some of the extremes may have been caused by the inclusion of parasitized larvae. Crochet number, however, is a reasonably accurate index to instar if the average number for the larva is obtained from at least three or four prolegs. As crochet number is apparently subject to as much variation as head-capsule width, it is

TABLE IV

The Range and Average Number of Crochets per Proleg of Spruce Budworm Larvae

Instar	No. of larvae	No. of prolegs counted	Total range	Range of larval averages	Mean No.
I	5	21	9 – 11	9.2 – 10.2	9.7
II	6	25	9 – 12	9.3 – 11.0	10.2
III	22	81	11 – 18	11.5 – 16.4	14.2
IV	31	119	15 – 30	16.0 – 30.0	21.4
V	35	132	22 – 49	23.3 – 47.3	34.2
VI	27	103	40 – 63	41.3 – 60.3	49.5

hardly reasonable to resort to this criterion except in doubtful cases where it is of considerable importance to establish the instar concerned. It does, however, provide a fairly sound basis for separating the troublesome third and fourth instars.

All the morphological and colour differences between the larval instars that have been noted above represent only gradations. They are not clear-cut characteristics and their interpretation depends to a considerable extent on the observer. When several characters are taken into consideration, however, a concept of each instar can be formed and identification becomes quite accurate. The following key, based on the main diagnostic features, has been prepared to aid in instar identification.

Key to the Larval Instars of the Spruce Budworm

1 Setal groups at base of each proleg and adjacent to the prothoracic spiracle, bisetose; head capsule less than 0.250 mm. wide and a pale amber colour; thoracic legs and prothoracic shield concolorous with the body ..... *First Instar*
Setal groups at base of each proleg and adjacent to the prothoracic spiracle, trisetose; head capsule more than 0.250 mm. wide; thoracic legs and prothoracic shield at least noticeably darker than the rest of the body 2

2 Head capsule not more than 0.325 mm. wide; thoracic legs darker than above; average number of crochets 11 at most ..... *Second Instar*
Head capsule more than 0.325 mm. wide; thoracic legs darker than above; average number of crochets more than 11 3

3 Head capsule not more than 0.500 mm. wide; crochets uniordinal and average number 12 to 16 ..... *Third Instar*
Head capsule more than 0.500 mm. wide; crochets at least imperfectly biordinal and average number more than 16 4

4 Head capsule not more than 0.900 mm. wide; prothoracic shield usually lighter in colour than the head capsule; average number of crochets 16 to 30 ..... *Fourth Instar*
Head capsule more than 0.900 mm. wide; prothoracic shield as dark as head capsule or, if not, has a conspicuous median line 5

5 Body cream-coloured above with no lighter coloured stigmatal band; prothoracic shield the same colour as the head capsule ..... *Fifth Instar*
Body brown above with a distinct light coloured stigmatal band; prothoracic shield usually lighter in colour anteriorly and along a conspicuous median line ..... *Sixth Instar*

Summary

A general study of the development of the spruce budworm was initiated in 1946 in the Black Sturgeon Lake area of northwestern Ontario where a large-scale outbreak was in progress. Certain phases of the investigation were continued until 1949. Special emphasis was placed on the needle-mining habits and

the number and separation of the larval instars. The duration of the various stages was studied, and differences noted between the sexes and among material collected from different host trees. The results of these more general studies are included in a general review of the life history of the spruce budworm.

The basic pattern of needle-mining activity on balsam fir trees was the same in all years irrespective of widely divergent weather conditions. Most larvae mine only one needle before entering the vegetative buds. A few larvae enter compact buds directly and a few mine additional needles. Comparisons were made with mining habits on spruce trees and a number of differences described. Larvae moult to the third instar before or after they leave the needle mines.

The number of larval instars was ascertained through individual rearing and the measurement of head capsules of larvae collected and preserved throughout the development period. The characteristic number of instars for field populations was six. In an attempt to find means of identifying the larval instars, the head width, setal patterns, colour patterns, and proleg crochets were studied. No single criterion was found to separate all instars, but using a combination of features a key was prepared which will establish the instar of most larvae satisfactorily. Head-capsule width is the best single criterion. It varies, however, between the sexes, females being larger, and is markedly influenced by certain parasites.

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Note on *Myzus ascalonicus* Doncaster (Homoptera: Aphidae), an Aphid New to North America

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In the potato storage cellar of the Fredericton laboratory, aphids were collected on March 1, 1954, from chrysanthemum cuttings that had been placed in the cellar during the autumn of 1953. The aphids were so numerous that they were causing severe injury to the plants. The writer identified the specimens as of *Myzus ascalonicus* Doncaster. This identification was verified by Mr. J. P. Doncaster, British Museum of Natural History.

Subsequently, while examining slides of aphids received from Mr. R. Glendenning, Agassiz, B.C., the writer observed specimens from carrot labelled tentatively as of *M. persicae* (Sulz.). When these were compared with the aphids from chrysanthemum they were identified as of *M. ascalonicus* Doncaster. Again, Mr. Doncaster verified the determination. According to Glendenning (in litt.) these aphids were collected at Chilliwack, B.C., October 10, 1947, from carrots that were being used in carrot rust fly studies; the aphids were extremely numerous and were noticed as a result of the abundance of coccinellid predators.

M. ascalonicus was first observed in England in 1941 but was not described until 1946 (Doncaster, 1946a). The apterous viviparous female is very similar to that of *M. persicae*. In the alate form, Doncaster (1946b) states, "The numbers of rhinaria on the antennae are extremely variable, and may range from a few near the base of the third joint to large numbers covering the whole of joints III, IV and V." The Fredericton and Chilliwack collections contained alate specimens with numerous sensoria on antennal segments III, IV, and V, and so were readily distinguished from *M. persicae*.

Doncaster (1946b) reported that the species is common in England on shallots in storage and on onions and other plants, in greenhouses and in the open, between October and June. He also states that it is an efficient vector of several plant viruses. This is the first known record of this species from North America.

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An Account of Insect Hallucinations Affecting an Elderly Couple

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Very rarely is an entomologist called upon to control the "insects" that are causing an obvious case of hallucinations. The following case history is of unusual interest because two people were involved, both having very similar experiences.

During November and December, 1952, Mr. and Mrs. X, aged 73 and 59 years, respectively, had been constantly plagued by an infestation of "bugs" in their well-kept farm home. The "bugs" were to be found in almost every part of the house at any time of the day, but were particularly bothersome during the night. Their bites were fearsome and occasioned a great deal of itching.

The elderly couple sought assistance at the Chatham laboratory only after describing their predicament to a daughter who had become alarmed at her parents' odd behaviour. They had become increasingly despondent and had developed a sense of shame because the "bugs" were associated in their minds with an unclean house. They stopped attending church, and received no visitors for fear of contaminating other people. It was with great difficulty that the couple explained the nature of their visit. Their particular case was indeed very real to them and it was obvious that an explanation blaming their plight on their imaginations would be most unsatisfactory and probably deleterious. Accordingly, a sympathetic attitude was adopted and, at their request, the house was thoroughly examined. There was absolutely no evidence of bed bugs, lice, fleas, or other undesirable creatures that would account for the couple's discomfort.

As the examination of the house progressed, both appeared more at ease and became voluble. After many questions, the following partial life-history of an imaginary insect was elicited from Mrs. X. Beginning as "thousands of tiny, pin-point specks that glitter like diamonds" and were found inside felt hats, on blankets, or on the bare abdomen, the "insects" hatched in a day. The resulting "larvae" were curled up in a ball, or assumed a U-shaped position and straightened out when prompted with the point of a pin but would not move thereafter. Apparently the "insects" had an incomplete metamorphosis for the "larvae" developed into little brown "bugs" in two days and travelled like "all-get-out". Some of the adults looked like small beans and, when on the person, felt like grains of sand. With only slight variations, Mr. X concurred with this description. He claimed he could actually feel the "bugs" walking over his body and estimated them to have 12 or 13 feet.

The couple had resorted to incredible measures to rid themselves and their home of their unwelcome guests. They employed a reputable fumigator, who, after conducting a thorough examination, advised them not to fumigate the house. Nevertheless, at their insistence, the house was fumigated and remained air-tight for three days while the couple lived in a chicken coop. (The author was confidentially informed that the fumigator could not see the "bugs" because his body was "full of poison" and, of course, the "bugs" would not come near him.) The fumigation seemed to help for a few days but the "bugs" soon returned. In desperation, they daily boiled all sheets, blankets, and wearing apparel and took three scalding baths each. They placed pillows, seat cushions, and other bulky items in the oven and scorched them to such an extent that they were discarded. They poured boiling water over the walls, chairs, and other

furniture and ruined the finishes on them. They burned a bed, couch, and mattress, and even sprayed the house, sheets, blankets, mattress, and all the rest of the furnishings with a seemingly promising mixture of carbolic acid, hot water, blue vitriol, rubbing alcohol, and a proprietary DDT spray.

The most pathetic admission on their part was that after his last bath of the day Mr. X allowed himself to be sprayed from head to toe with a weak mixture of carbolic acid and DDT emulsion before retiring. This apparently gave some relief, but by two or three o'clock in the morning he could no longer sleep because of the "bugs". He would then get up, stoke the kitchen fire, and doze in his rocking chair for the rest of the night. It was during one of these sessions that Mr. X had his most frightening experience. In his own words, "the bugs came down the wall, marched in single file across the room, ran up my leg under my underwear, and came out my neck and disappeared".

Mrs. X reluctantly admitted that the "bugs" were worse where the clothing was tight against the body and that she was forced to remove her corsets three or four times daily for relief. They had sought medical attention and were supposedly treated for scabies. They estimated they had spent between 20 and 30 dollars on various pills, ointments, and lotions, and a look into their medicine chest convinced the author that this was a conservative figure.

It was a source of dismay to the couple when the examination of the house yielded no insects. The "bugs" had become so common that they were taken for granted. A small vial of alcohol and a camel's hair brush were left with the couple with instructions to capture a few specimens and bring them to the laboratory, where they could be examined under a microscope.

Within two days, the couple returned to the laboratory with their preserved specimens and excitedly explained that the "bugs" had re-appeared shortly after the house had been examined. Although an examination of the contents of the vial revealed nothing but a few particles of dirt and pieces of lint, the couple was assured that "there was strong evidence of an infestation but that a recently discovered chemical would eliminate the insects". They were also told that theirs was not an unusual case and there was certainly no reflection on the housekeeping abilities of Mrs. X. They were given a small amount of the "new chemical", 25 per cent DDT emulsion, with detailed instructions on how and where to apply it. It was also pointed out that three or four treatments over a month would be necessary before elimination of the insects could be expected.

Almost one month to the day, the couple returned to the laboratory and gratefully reported the total disappearance of the "bugs". For the first time in three months, they were sleeping throughout the night, their health and general well-being had improved immeasurably, and they were once more attending church and receiving visitors.

The foregoing account is related because the method of handling the problem brought about a happy ending. For others, whose normal occupations may some day be interrupted by an unexpected request for assistance in alleviating the distress of a victim of insect hallucinations, the following points may be worth consideration.

1. Become interested in the case and sympathetic. However ludicrous the situation may appear to the investigator, the problem is very real and disturbing to the individual concerned. A casual explanation of "imagining things" would probably do more harm than good.

2. Encourage him to talk freely. Once unburdened, he feels as though his problem is shared and, consequently, is more receptive to any adjustment program.

3. Suggest that his descriptions and experiences tally with other cases you have dealt with and that the cure is relatively simple.

4. Follow up the case with two or three personal calls during the adjustment period. The presence of an interested person who knows the case history and who offers encouragement apparently carries considerable weight with these disturbed individuals.

Notes on the Spruce Needle Miner, *Taniva albolineana* Kft. (Olethreutidae: Lepidoptera)[1]

By MARGARET E. P. CUMMING[2]
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Introduction

The spruce needle miner was first described by Kearfott in 1907 (4), as *Lipoptycha albolineana* sp. nov. It was given various names by different authors after that time, and in a revision by Heinrich (3) was placed in the new genus *Taniva*.

The larvae of the spruce needle miner feed within the needles of spruce. They form a nest with the dead needles and frass held together with webbing. Ornamental trees are more often infested than forest trees. Young trees growing under adverse conditions are particularly susceptible to serious injury.

The spruce needle miner commonly infests planted white, and blue spruce, and native spruces in Alberta, Saskatchewan, and Manitoba, and is present on Chinese spruce at the Forest Nursery Station, Indian Head, Sask. Brown (1) reported that it was present on Englemann, white, Norway, and blue spruce especially in plantations, in British Columbia, Ontario, Quebec, and the Maritimes in Canada. Weigel and Baumhofer (5) reported that the insect is widely distributed in the United States and occurred on blue, Norway, and Engelmann spruces.

Much of the information for this paper was obtained from a heavy infestation on Chinese spruce, *Picea asperata* Mast., at the Forest Nursery Station, Indian Head, Sask. in 1944. The trees were fifteen years old, but had attained a height of only 5 feet. The buds of each year's growth had been winter killed in all but the mildest winters. Other information has been gathered from collections sent in through the Forest Insect Survey at the Indian Head Laboratory from 1943 to 1953.

Description and Habits

The eggs are pale yellow and are round, ridged and flattened as if they had dried after being laid. They are laid along the side of a spruce needle, deposited from the base toward the tip, each egg slightly overlapping the preceding one, and occupying the width of the needle. In ten egg clusters observed in field collections the number of eggs varied from three to ten; the average was six. Craighead (2) states that the incubation period is 10 to 12 days.

The newly hatched larvae are yellow, but become pale green in colour with light brown head capsules after commencing to feed. Two newly hatched larvae were each 0.75 mm. long with a head-capsule width of 0.18 mm. Full-grown larvae are darker green with darker brown head capsules than the young

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larvae. The maximum body length is 8.00 mm., with a head-capsule width of 0.62 mm.

Some larvae hatch as early as mid-June, and others much later. The young larvae feed near the needle where the eggs were laid, or move in a group to other needles. Feeding takes place in old needles. Each larva cuts a circular opening at the base of a needle and mines toward the distal end. The frass is deposited outside the needle. Usually only one larva mines in a needle, but occasionally two young larvae are found. A small larva may mine along one side of a needle, but later the entire content of a needle is eaten, leaving only the epidermis. The entrance hole is later used as an exit. Craighead (2) states that each larva will destroy an average of 10 needles on blue spruce. Feeding continues until October and recommences in the spring until mid-May or early June. It is not known if all the larvae feed in the spring, but some do, as freshly mined needles have been found. Head capsule measurements show that some larvae reach the maximum size in the fall, but others do not.

Moulting of young larvae probably takes place within the needles. During the summer and fall, larvae are rarely found outside the needles. Often a larva, and two or three cast head capsules are found within a single needle. In the spring, cast head capsules are sometimes found in the frass and webbing.

Most of the larvae construct hibernacula of silk with frass adhering to the outside, but some may overwinter in the needles, as larvae are often found in mined needles in the fall, with frass and webbing across the entrance. The hibernacula resemble loosely constructed cocoons.

The average number of larvae in a nest does not exceed the average number of eggs laid in one row, so it is likely that the larvae from one row of eggs form one nest. The nests are masses of frass and dead needles held together by fine webbing. Empty nests may persist a year or more. They usually occur near the bases of the large branches of the tree, in the thickest growth. On small trees they are commonly found on the lower crown, next to the trunk. Usually only one twig is involved in a nest, but where branches are close together twigs from two or three branches may be included. Some vacant nests are

Fig. 1. A small nest formed by the spruce needle miner on needles of white spruce.

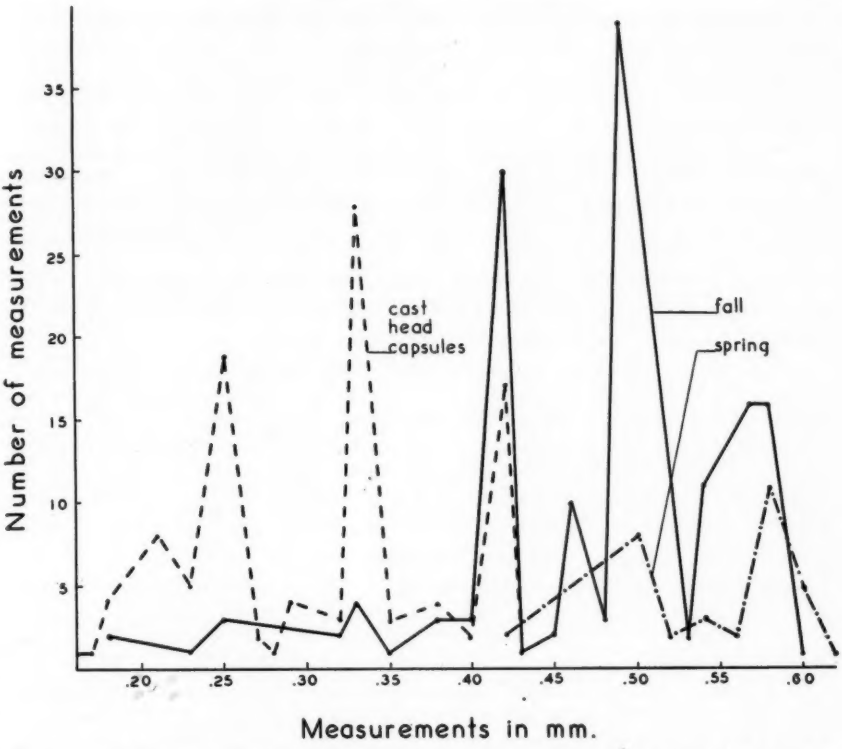

Fig. 2. A simple distribution diagram of measurements of head capsules and cast head capsules of larvae of the spruce needle miner.

present in the fall, indicating that the larvae may move to a new site. Early in August as few as five mined needles may occur in a nest, but by the end of September there may be as many as 40. In 124 nests examined the number of larvae ranged from one to eleven with an average of three. Fig. 1 shows a typical small nest on a twig of white spruce.

Measurements of head capsules indicate that there are six instars. Fig. 2 is a simple distribution diagram of the measurements. The measurements of cast head capsules apparently represent the width of the head capsules of living larvae; in the fourth peak of the diagram the cast head capsule measurements and those of living larvae correspond. "Spring" and "fall" measurements are recorded separately because a size variation was found between the late fall and spring measurements. The diagram presents 34 "spring" measurements and 148 "fall" measurements of larvae, made in 1944 and 1953, and 103 measurements of cast head capsules made in 1944.

The early pupae are light green in colour; as development takes place the abdomens become brown, and grey scales become visible. The pupal stage is passed in the nest within cocoons made of frass held together with webbing and lined with fine white silk. Occasionally a larva forms a case of needles held together side by side before constructing its cocoon within.

Pupae and larvae are both present in nests in May and early June. The earliest examination of nests was made on May 9, 1944. At that time half the insects were early pupae. The first adult emergence record from these nests was May 20. The period of pupal development was at least ten days; since some development of pupae had taken place, it was probably closer to two weeks.

Pupae are present in the field over a long period of time. In five field cages (celluloid cylinders with cloth at both ends) fastened to twigs in 1944, adults emerged from May 27 to June 26, a period of four and one-half weeks. A total of 36 adults emerged from these cages; 20 of these emerged in the first week, and 13 in the next two weeks.

The adults are small, grey-brown moths with a wing expanse of 11 to 15 mm. In the field moths were observed resting in the shade, on the thickest growth of the spruce trees. This is where oviposition occurs.

Thirty-two moths from the field cages were introduced into lamp-chimney cages in the insectary in order to observe oviposition habits. During the daytime the moths were inactive and rested on the twigs or cage floors. Very few eggs were laid, some on the needles and others on the cage floors. They were laid in rows or were scattered, not more than six being deposited in one place. Under cage conditions the average length of life of 13 males was 7.4 days, of 19 females, 9.6 days.

Parasites

Two species of Ichneumonidae and five species of Braconidae were obtained from the spruce needle miner. The Ichneumonidae were *Itoplectis quadricingulatus* (Prov.) and *Horogenes* sp. The Braconidae were *Agathis bicolor* (Prov.), *Apanteles*, two species, *Ascogaster* sp., and *Bracon* sp.

Ascogaster sp. was the most common parasite. It was obtained from collections from various places in Alberta and Saskatchewan; in some collections there was a high percentage of parasitism by this species.

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North American Species of *Streptanus* (Homoptera: Cicadellidae)[1]

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There has been much confusion between the North American species of leafhoppers of the genus *Streptanus* Ribaut, partly because the species are so closely related and partly because the extent of the variation in markings and wing length was not fully appreciated. Four species have been found in North America, of which three have been recorded previously. The four are conspecific with species described from Europe, and the specific names that have been applied to North American species must be reduced to synonymy.

Key to Species (Males)

1 Aedoeagus with one or two dorsolateral projections near base of shaft 2
Aedoeagus without such projections 3

2 Expanded apical region of aedoeagus obviously longer than wide; shaft with two dorsolateral projections near base (Fig. 1) ..... *sordidus* (Zett.)
Expanded apical region of aedoeagus not longer than wide; shaft with a single dorsolateral projection near base (Fig. 2) ..... *aemulans* (Reut.)

3 Expanded apical region of aedoeagus as long as or longer than wide (Fig. 3) ..... *confinis* (Reut.)
Expanded apical region of aedoeagus much shorter than wide (Fig. 4) ..... *marginatus* (Kirsch.)

Streptanus sordidus (Zett.)

Fig. 1

Thammotettix sordidus Zetterstedt, 1828: 295.
Jassus (Athysanus) confusus Kirschbaum, 1868: 107.
Athysanus fraterculus Reuter, 1880: 211.
Athysanus relativus Gillette and Baker, 1895: 93. New synonymy.
Athysanus lindbergi Baker, 1925: 160. New synonymy.

Length 3.4-4.0 mm. The forewings are shorter than the abdomen in both sexes. The form of the aedoeagus is distinctive. The female seventh sternum was figured by Sleesman (1930). Judged from that figure, it has a larger tooth at the middle of the posterior margin than other species of the genus.

This species has been recorded (as *relativus*) from localities in the northern regions of the United States and from British Columbia. Specimens from British Columbia and New Brunswick were examined.

Streptanus aemulans (Kirsch.)

Figs. 2, 5

Jassus (Athysanus) aemulans Kirschbaum, 1868: 107.
Jassus (Athysanus) minkii Kirschbaum, 1868: 108.
Euscelis sahlbergi Reuter, 1880: 220.

There are two forms of this species. One has the forewings shorter than the abdomen in both sexes, the body and forewings heavily marked with blackish-fuscous, and the dorsolateral projection near the base of the shaft of the aedoeagus usually rounded, and is 4.0 to 4.5 mm. in length. The other has the forewings longer than the abdomen in both sexes, the forewings less heavily dark-marked except along the costa, and the dorsolateral projection near the base of the shaft of the aedoeagus usually fore distinctly pointed, and is 5.0 to 5.5 mm. in length. The form of the aedoeagus is distinctive. The female is often difficult to distinguish from those of related species, but the two crescent-shaped dark markings that are confluent at the median tooth of the seventh sternum are rather distinctive when not obscured by darkening of the sternum.

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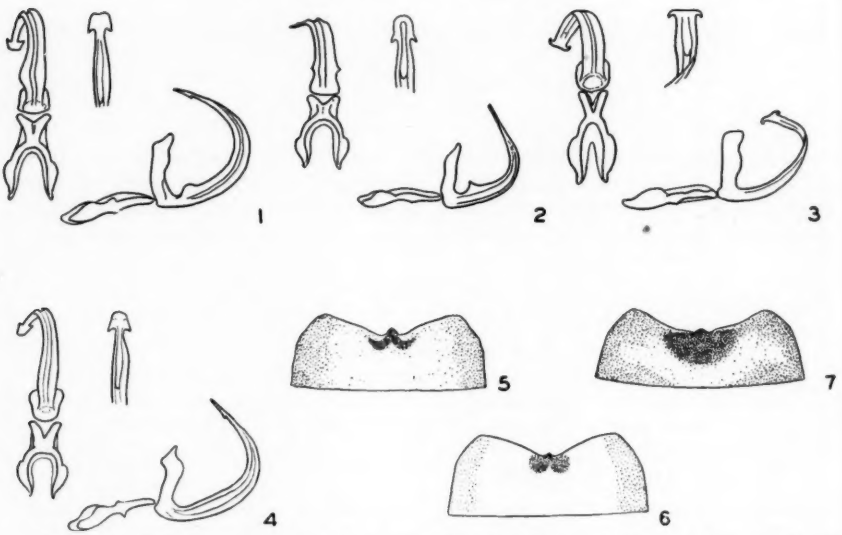

Figs. 1-7. *Steraptanus* spp. 1-4, Aedoeagus, lateral and ventral views, and posterodorsal view of apical region: 1, *S. sordidus* (Zett.); 2, *S. aemulans* (Kirsch.); 3, *S. confinis* (Reut.); 4, *S. marginatus* (Kirsch.). 5-7, Female seventh sternum of: 5, *S. aemulans*; 6, *S. confinis*; 7, *S. marginatus*.

It is difficult to evaluate previous records because of confusion with other species. DeLong and Knull (1945) and Oman (1949) listed *deceptus* as a synonym of *sahlbergi*, following Sleesman's (1930) suggestion; *deceptus* is treated here as a synonym of *confinis*. Specimens were examined of the short-winged form from a locality in the Yukon and of the long-winged form from localities in Alaska and British Columbia.

***Streptanus confinis* (Reut.)**

Figs. 3, 6

Athysanus confinis Reuter, 1880: 211.
Euscelis deceptus Sanders and DeLong, 1917: 87. New synonymy.
Euscelis wagneri Ossiannilsson, 1944: 14.

There are two forms of this species. One has the forewings shorter than the abdomen in the female and the forewings more distinctly dark-marked, and is 4.5 to 5.0 mm. in length. The other has the forewings longer than the abdomen in both sexes and the forewings weakly dark-marked and sometimes almost wholly pale, and is 5.0 to 5.5 mm. in length. The form of the aedoeagus is distinctive. The female seventh sternum resembles those of related species but the two confluent, rounded, dark areas below the median tooth are rather distinctive when not obscured by darkening of the sternum.

The long-winged form was described as *deceptus*. DeLong and Knull (1945), following Sleesman's (1930) suggestion, listed *deceptus* as a synonym of *sahlbergi*, listed here as a synonym of *aemulans*; and Oman (1949) listed *deceptus* as a synonym of *relativus*, listed here as a synonym of *sordidus*. The type of *deceptus*, from Wisconsin, and other specimens of the long-winged form from localities in Manitoba and Alberta were examined, and specimens of the short-winged form were examined from localities in Quebec, Alberta, and British Columbia.

***Streptanus marginatus* (Kirsch.)**

Figs. 4, 7

Jassus (*Athysanus*) *marginatus* Kirschbaum, 1858: 5.
Jassus (*Athysanus*) *brevipennis* Kirschbaum, 1858: 9.
Jassus (*Athysanus*) *similis* Kirschbaum, 1868: 114.
Euscelis hyperboreus Van Duzee, 1919: 4. New synonymy.

A relatvely small species, 3.5 to 4.5 mm. in length. The forewings are as long as or slightly longer than the abdomen in the male, shorter than the abdomen in the female. The female seventh sternum tends to be marked more heavily with black than in other species of the genus, and the median tooth is relatively small. A rather distinctive feature is that the dark transverse band of the vertex is usually unbroken, whereas in other species of the genus it is usually broken in the middle. The form of the aedoeagus is distinctive.

Specimens, including the type of *hyperboreus*, from localities in the Yukon, Northwest Territories, and Alaska were examined.

Acknowledgments

This study was based largely on material in the Canadian National Collection, much of which was obtained in the Northern Insect Survey, a joint project of the Entomology Division, Department of Agriculture, and the Defence Research Board, Department of National Defence. The author wishes to thank Professor D. M. DeLong, Ohio State University, Dr. Frej Ossiannilsson, Uppsala, Sweden, and Dr. David A. Young, Jr., Bureau of Entomology and Plant Quarantine, United States Department of Agriculture, for the loan of specimens.

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Observations on the Duration of the Pupal Stage of Ten Species of Mosquitoes Reared at London, Ontario[1]

By W. W. Judd[2]

The writer (Judd, 1954) reported upon the results of a survey of mosquitoes conducted at London, Ontario in 1952, during which seventeen species were found to occur. Larvae and pupae were taken from pools in six areas in London and its vicinity and were reared to the adult stage at room temperature in the laboratory. Each larva or pupa to be reared was placed in a separate small jar covered with cheesecloth and containing some of the water from the pool from

Table I

Number of larvae reared to the adult stage

Species Reared	Duration of Pupation										Number reared			Period of Rearing
	1 day		2 days		3 days		4 days		5 days					
	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	Total	
Anopheles punctipennis (Say)			1	3							1	3	4	July 27–Aug. 24
Anopheles quadrimaculatus (Say)			1	1	1						2	1	3	June 10–Aug. 2
Culiseta inornata (Williston)					2	3	2	1			4	4	8	May 4–May 22
Aedes stimulans (Walker)			1	2	6	3	3	2	1		11	7	18	Apr. 16–May 10
Aedes fitchii (Felt and Young)						1	1	2			1	3	4	May 8–May 17
Aedes vexans (Meigen)			1	7							1	7	8	June 3–Aug. 25
Aedes canadensis (Theobald)				1				1				2	2	May 11–May 15
Culex pipiens L.	4	18	11	13	2	3		1			17	35	52	May 23–Sept. 12
Culex restuans (Theobald)			1	4							1	4	5	July 12–Aug. 19
Culex apicalis (Adams)	1			2							1	2	3	July 19–Aug. 16
	23		49		21		13		1		39	68	107	

which the specimen had been taken. As the insect went through its series of moults the exuviae were preserved and a record was kept of the dates on which moults occurred. One hundred and seven larvae, representing ten species, successfully passed through the pupal stage to produce adults. The data accu-

1Contribution from the Department of Zoology, University of Western Ontario; a project supported by funds from the government of Ontario on recommendation of the Advisory Committee on Fisheries and Wildlife of the Research Council of Ontario.

2Associate Professor of Zoology.

mulated from these rearings thus give information concerning the length of the pupal period of the species represented. This information was not included in the publication referred to above and is presented herewith in Table 1.

The pupal period of the insects reared lasted from one to five days. Most of them, 72, emerged after only one or two days in the pupal stage and the remainder, 35, after three to five days. The species in which the majority of insects showed the longer periods of pupation (e.g. 3-5 days) were those collected as larvae during April and May, i.e. *Culiseta inornata* (Williston), *Aedes stimulans* (Walker) and *Aedes fitchii* (Felt and Young). Species in which the majority of insects pupated for only one or two days were those collected from pools mostly during the summer months, June to August, i.e. *Anopheles punctipennis* (Say), *A. quadrimaculatus* Say, *Aedes vexans* (Meigen), *Culex pipiens* L., *Culex restuans* Theobald and *Culex apicalis* Adams.

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(Received July 9, 1954)

Differential Growth as Evidence of the Relationship of *Monochamus notatus* (Drury) and *M. scutellatus* (Say) (Coleoptera: Cerambycidae)[1,2]

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Monochamus notatus (Drury) and *M. scutellatus* (Say) are both common wood-boring beetles in the coniferous forests of eastern Canada. The two species are usually separated on the basis of colour. The first is dark brown with lighter brown elytra, and is covered with white and brown pubescence, while the second is typically shining black. The scutellum of each bears a dense white pubescence which, in the case of *M. notatus*, is divided by a bare median line. Such a line also occurs in *M. scutellatus* but is usually incomplete. The writer has found that the presence or absence of a fringe of white hair around the compound eye constitutes the most consistent anatomical difference between the two species, it being present only in *M. notatus*. The elytra of the females of both species are generally marked with elongate spots. Body length is also used to separate the two species, but no clear-cut difference in length ranges occurs; instead, there is considerable overlap.

It is also apparent in the field that the two species act almost as one population. Both species cause the same type of damage in dead trees and logs, and breed freely in the same locality at the same time and in the same hosts. It is practically impossible to distinguish between the larval forms. Furthermore, the writer obtained evidence of occasional interspecific mating when the males and females of both species were caged together, although this occurred too infrequently for critical evaluation. The study of differential growth in the two species was undertaken to test for further evidence of the close relationship between them. All the specimens studied were collected during 1949 and 1950,

[1]Contribution No. 159, Forest Biology Division, Science Service, Department of Agriculture, Ottawa, Canada.

[2]Based on part of a thesis submitted to McGill University in partial fulfilment of the requirements for the Degree of Master of Science.

in the portion of the Mississagi valley of central Ontario which was burned in 1948. It is probable that most of the material had emerged from fire-killed white, red or jack pine trees.

It has long been known that different parts of many animals grow at different rates so that, as growth proceeds, the ratio of the size of one part to that of another varies with the size of the animal. This phenomenon of differential growth was illustrated by Thompson (1917) by a system of Cartesian transformations which, however, did not afford any general expression of differential growth.

Huxley (1932) discussed the problem of differential growth ratios of various parts of animals. He showed that if y be the magnitude of the differentially growing organ, and x the magnitude of the animal or an organ with which y is compared, then the formula $y = bx^k$ expresses the ratio between them. This has come to be known as the simple allometry formula. The terms b and k are constants; b is the *initial growth index*, and k has been termed the *equilibrium constant* (Huxley and Teissier, 1936).

The formula is often written: $\log y = \log b + k \log x$. Thus, to demonstrate that an organ exhibits differential growth, it is necessary only to show that the plotted logarithms fall in a straight line. The slope of the line is the value of k. If the angle between the line and the X-axis be 45°, then the value of k is unity, a condition termed *isometry*. If k be greater or less than unity, the organ is said to exhibit *positive* or *negative allometry*.

Allometric studies have been carried out on a variety of animals ranging from small marine arthropods to large mammals. Holometabolous insects present a special case in that they achieve adult form "all at once" during the pupal stage. It is impossible, therefore, to study the relative growth of different parts of these animals during time. In this case, the simple allometry formula is particularly useful in that the growth coefficients of parts may be determined from measurements made on the adult animal. The ratio between the sizes of different parts is brought about by differential growth preceding maturity. That a form of growth takes place in the limbs of these animals is well known. Embryonic rudiments of the imaginal limbs occur early in larval development and may grow slowly throughout immature life. The limb buds thus developed differentiate during the pupal stage to form the definitive adult limbs. Thus, there exists a condition comparable with growth in other animals.

In the present study, the regression of y on x has been calculated from ungrouped data. The use of regression in allometry was proposed by Schmalhausen and by Feldstein and Hersh (Richards and Kavanagh, 1945). The regression coefficient is k, the equilibrium constant. The advantages of calculating the regression are evident: the line is obtained mathematically, and the significance of regression and of the differences between regression coefficients for different samples may be tested.

The significance of the difference between the values of k for the same organ in different animals is important. Widely different values of k for similar animals should indicate that they are not closely related. Huxley (1932) showed that the laws of growth may be used in this manner to test the validity of species, subspecies and "forms". Newcombe (1949) stated that the allometric method is of potential use in comparing differential growth rates in geographic varieties as well as closely related species. Reid (1942) found considerable interspecific differences in the values of k for various organs in *Laemophloeus* beetles.

The elytra of *Monochamus* cover the body from the mesothorax to the tip of the abdomen. In this way, their length is a function of the total length of the

TABLE I

Mean, standard deviation, and observed range of elytral length
Measurements in centimetres

	M. notatus				*M. scutellatus*			
Sex	N	Mean	S.D.	Range	N	Mean	S.D.	Range
Male.....	46	1.90	.28	1.29–2.29	37	1.29	.22	0.85–1.73
Female.....	54	2.01	.23	1.43–2.38	42	1.42	.17	1.13–1.72

insect, and is used in this study as the standard dimension, x. As shown in Table I, the mean lengths of the elytra differ markedly although there is a considerable overlap in range.

The organ tested for differential growth was the tibia of the foreleg. This is easy to measure accurately and displays an interesting sexual dimorphism. At the beginning of the study, measurements were also made of the third antennal segment. These were discontinued, however, as they were found to be the same as those of the fore tibia on the same individuals. Thus all of the data, including equilibrium constants, apply equally to the third antennal segment.

Measurements were made using dividers and scale on pinned, dried specimens under a mounted reading glass. For the sake of uniformity, all measurements were made of the left elytron and the tibia of the left foreleg. The lengths of these organs were measured on 100 specimens of *M. notatus* and 79 specimens of *M. scutellatus*. The data, with elytral lengths grouped for convenience, are shown in Tables II and III. The mean lengths of elytron and tibia, and their ratio, are given for each group. The aforementioned sexual dimorphism of the fore tibia is well demonstrated by the difference between the tibial lengths for

TABLE II

Measurements in centimetres of lengths of left elytron
and tibia of left foreleg in *M. notatus*

Elytral length groups	No. of specimens per group	E Mean elytral length	T Mean tibial length	T/E
	46 males			
1.26 – 1.45	7	1.39	0.63	0.45
1.46 – 1.65	3	1.58	0.83	0.52
1.66 – 1.85	5	1.79	0.95	0.53
1.86 – 2.05	17	1.98	1.13	0.57
2.06 – 2.25	10	2.13	1.25	0.59
2.26 – 2.45	4	2.28	1.32	0.58
	54 females			
1.46 – 1.65	6	1.57	0.48	0.31
1.66 – 1.85	9	1.75	0.56	0.32
1.86 – 2.05	12	1.97	0.62	0.31
2.06 – 2.25	21	2.17	0.69	0.32
2.26 – 2.45	6	2.32	0.75	0.32

TABLE III

Measurements in centimetres of lengths of left elytron and tibia of left foreleg in *M. scutellatus*

Elytral length groups	No. of specimens per group	E Mean elytral length	T Mean tibial length	T/E
	37 males			
0.66 – 0.85	1	0.85	0.37	0.44
0.86 – 1.05	8	1.02	0.46	0.45
1.06 – 1.25	9	1.20	0.58	0.48
1.26 – 1.45	7	1.32	0.64	0.48
1.46 – 1.65	10	1.52	0.81	0.53
1.66 – 1.85	2	1.70	0.91	0.53
	42 females			
1.06 – 1.25	9	1.19	0.39	0.33
1.26 – 1.45	15	1.36	0.46	0.34
1.46 – 1.65	15	1.56	0.53	0.34
1.66 – 1.75	3	1.71	0.59	0.35

the two sexes. Also, it can be seen that in the males of both species, and possibly in the females of *M. scutellatus*, the ratio of tibial length to elytral length is greater in large insects than in small ones. This increase in ratio with increase in size is quite distinct in the males, but is practically imperceptible in the females. Since it is due to differential growth, it will be shown better by the values of the equilibrium constant, *k*.

Fig. 1 shows the graphs obtained by plotting the logarithms of the measurements. The lengths are multiplied by ten to avoid negative logarithms. The regression lines fit the data very closely, and in each case the test of linearity shows a high significance (P less than .00001). Interspecific differences in elytral length, and intraspecific sexual differences in allometric growth of the fore tibia are evident. It is also noteworthy that the specimens of *M. scutellatus* are much more evenly distributed by size (elytral length) than are those of *M. notatus*.

Table 4 gives the values of *k* for both sexes of each species. In all cases, the fore tibia exhibits positive allometry although its growth is practically isometric in the case of the females. The difference between the values of *k* for the males and females of *M. notatus* is greater than that between the values of *k* for the two sexes of *M. scutellatus*. The difference in *k* for the females of the two species (1.14 and 1.15) is not significant. The difference between the values of *k* for the males, although somewhat greater, is also not significant (P = .93 approx.).

TABLE IV

Values of *k* for tibia of left foreleg

Sex	*M. notatus*	*M. scutellatus*
male	1.52	1.38
female	1.14	1.15

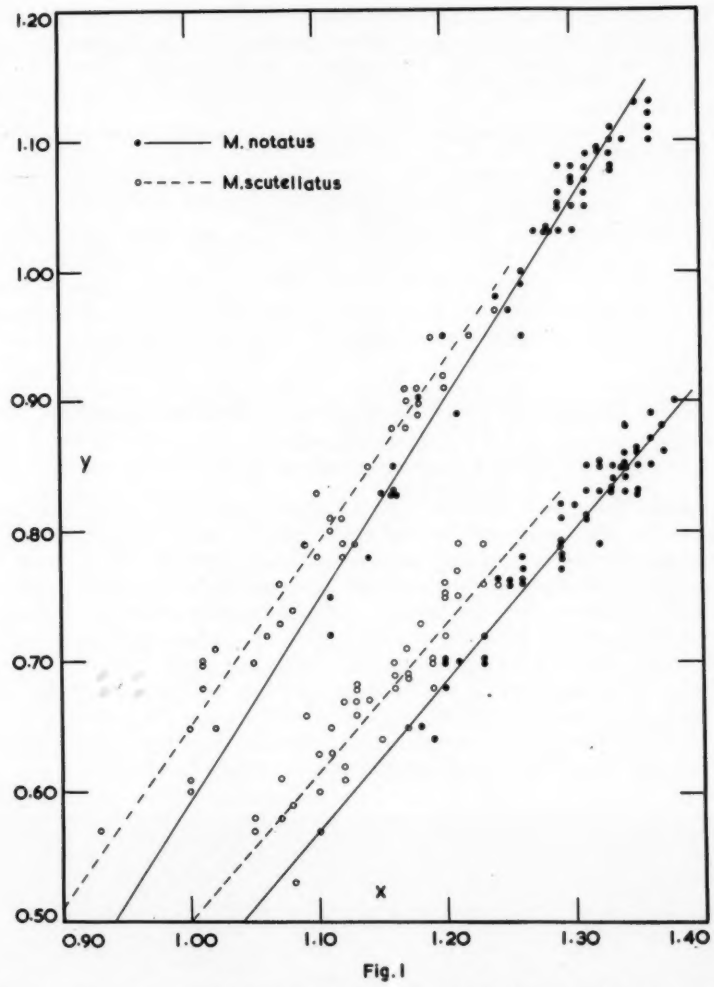

Fig. 1. Logarithmic plotting of fore tibial lengths, y, against elytral lengths, x. Lengths have been multiplied by 10. Upper, males; lower, females.

The similarity in allometric growth of the fore tibia in *M. notatus* and *M. scutellatus*, while it may not by itself threaten the validity of the separation of the two species, can be looked on as another indication that they are very closely related. Differences in mean elytral length (Table 1), body colour, and presence or absence of a fringe of hair on the margin of the compound eye suggest that they are different species. Similarities in life history, habits, hosts and larval form, as well as allometric growth of the fore tibia and third antennal joint, are indicative of a very close relationship between the two. This is further emphasized by the observation of cross mating between them under artificial conditions. Critical studies of mate choice and of any resulting progeny are needed to clarify further the relations between the two species.

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An Apparatus for Mounting and Holding Insects

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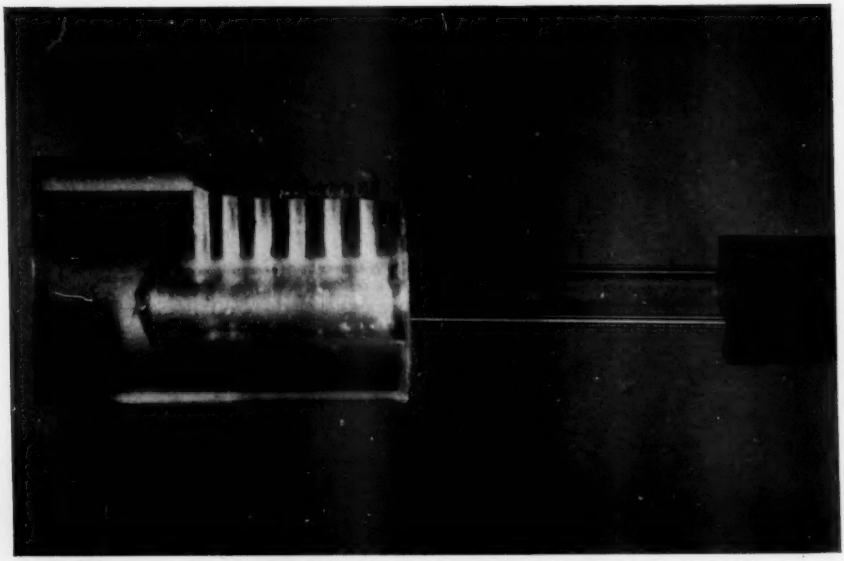
Occasions frequently arise in entomological work when it is necessary to hold an insect absolutely still in order to operate upon it. A year ago an apparatus was devised for holding sawfly larvae for injection. It has now been improved and is being currently used to hold sawfly larvae quiet while substances are introduced into the midgut. The apparatus, shown in the accompanying figure, consists of a grooved plastic platform with small holes in the base. These holes are connected to a vacuum line. A water pump may be substituted very nicely. The larva can be placed in any position on the platform by lifting it on a stick and pressing it lightly over the holes on the platform. The larva can be freed immediately by releasing the vacuum. As long as the vacuum is regulated carefully, there are no harmful effects upon the larva.



An Outbreak of the Larch Sawfly (*Pristiphora erichsonii* (Htg.)) in the Maritime Provinces (Hymenoptera: Tenthredinidae) and the Role of Parasites in its Control[1]

By W. A. Reeks[2]
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At least four outbreaks of the larch sawfly, *Pristiphora erichsonii* (Htg.), have occurred in the Maritime Provinces within the past 70 years. The first (1) occurred from about 1883 to 1885, the second from about 1906 to 1909 (1), and the third from 1919 to 1927. The last outbreak started in 1933 and ended in 1942. Despite extensive sampling by the Forest Insect Survey from 1943 to 1953, only six samples have been taken during this period in the three Maritime Provinces, and each was an isolated colony. Although an ecological study of the insect was not attempted during the latest outbreak, general observations were made by the writer and other staff members of the Survey. These observations are summarized in the present paper to record the outbreak and some of the factors that contributed to its termination. Another outbreak has persisted in Newfoundland from 1942 and perhaps earlier, but the present discussion is largely confined to events in New Brunswick, Nova Scotia, and Prince Edward Island.

Methods

Most of the work consisted of the rearing or dissection of field-collected larvae and cocoons. The work was done near Fredericton, N.B., and collections were made at many points throughout the region.

Cocoons were collected at random in the fall or early spring for parasite recovery. These were placed in wooden boxes with wire-screen tops and bottoms for emergence. The cocoons were covered lightly with moss, and the boxes were placed on the forest floor under natural shaded conditions. A few collections were brought in about the first of March for incubation at a controlled temperature of 72°F. and relative humidity of 80 per cent. However, these conditions did not appear to be ideal for breaking diapause in one of the ichneumonid parasites, so all other lots were left outdoors for emergence.

Approximately 8,000 cocoons were collected on May 3 and August 29, 1939, for following the development of the sawfly and its parasites within the cocoon. These were thoroughly mixed and divided into lots of about 200 cocoons. Each lot was placed outdoors in a cage as described above. A cage was brought in about twice weekly during the fall, spring, and summer months, and the stages of the sawfly and its parasites noted. The seasonal occurrence of sawfly larvae was determined from periodic collections.

A few oviposition counts were made to determine if there was a change in fecundity as the outbreak progressed. Those reported here are restricted to adults that originated from one stand at Oak Bay, N.B., in different years, but the results were similar to those noted for other localities. In each case, recently-emerged adults were placed in shaded wire-screen, sleeve cages, which enclosed living branches of larch. Following oviposition, the adults were dissected to determine the number of remaining oocytes. Limitations of time prevented a study of sawfly populations. Instead, notes were kept on defoliation of larch trees. Defoliation was classified as follows: Light, trace to 20 per cent defoliation; moderate, 30 per cent to 60 per cent defoliation; and severe, 70 per cent to 100 per cent defoliation.

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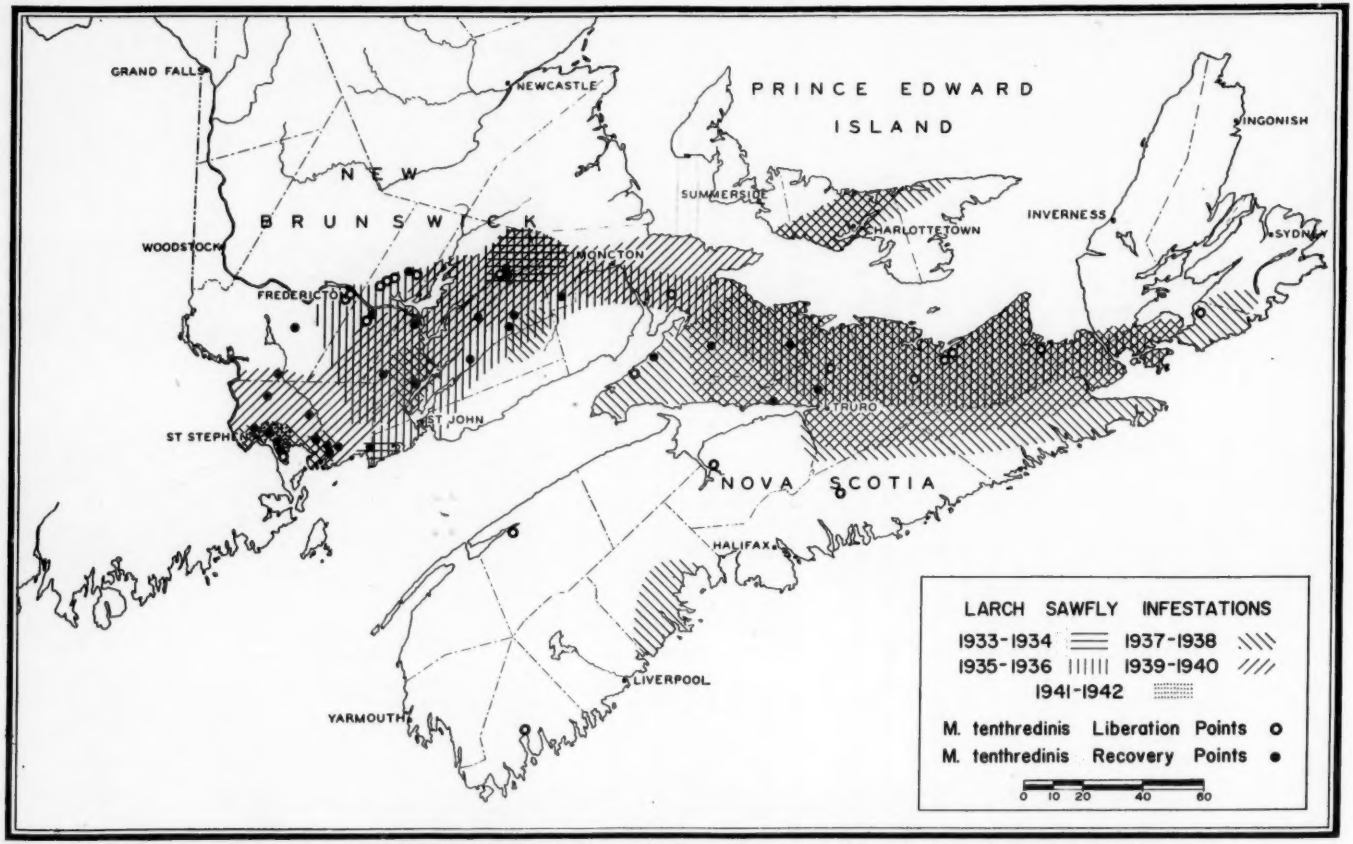

Fig. 1. Moderate to severe infestations of the larch sawfly from 1933 to 1942 shown in 2-year intervals, and points where colonies of *Mesoleius tenthredinis* Morley were released and subsequently recovered in the Maritime Provinces.

History of Outbreak

The last outbreak started near Lepreau, N.B., in 1933. The infestation increased considerably in area in 1934, when larch stands on the lower St. John River and the Canaan River drainages were severely defoliated. It eventually covered most of the southern half of New Brunswick, the peak occurring about 1937. Larch stands near St. Andrews and Oak Bay were the latest to be attacked, and severe infestations persisted in these areas until 1942. Stands in northern New Brunswick were very lightly attacked during the outbreak period.

The outbreak in Nova Scotia occurred from about 1935 to 1941. The most severe infestations were seen in the counties of Cumberland, Colchester, and Pictou on the mainland, and in Richmond County on Cape Breton Island. Light infestations were common throughout the greater part of the Province by 1938. The peak of the outbreak occurred about 1939, and it ended in 1942.

Complete records for Prince Edward Island are lacking, but light to moderate infestations occurred in the central and northeastern coastal regions from 1937 to 1939.

As infestations enlarged, severe attack was most apparent in peripheral areas, and the first improvement in the condition of the trees occurred at the epicenters. Severe infestations rarely persisted in a stand more than four years and never more than five years. Hence there was considerable annual variation in infestation classes. The approximate distribution of moderate to severe infestations is shown in 2-year intervals (Fig. 1). The severity of attack was often irregular, ranging from severe in one stand to light in an adjacent stand. Pure stands of larch up to 20 years of age were relatively free from attack. Tree mortality was light. The highest estimated mortality was in the coastal area of St. John and Charlotte counties, where it ranged from less than 1 per cent to 5 per cent of the trees. Twig mortality in the same region ranged from 10 per cent to 50 per cent, and it was severe wherever defoliation exceeded 70 per cent for three or four successive years.

Life History of Sawfly

The sawfly is essentially univoltine. A very small emergence of second-generation adults occurred in some years but never exceeded 2 per cent of the reared cocoons under field conditions. In one lot of about 500 emergents, 5 per cent were in diapause two years, but 2-year diapause occurred in only 1 per cent of all cocoons reared. Reproduction was by thelytokous parthenogenesis, and 99.3 per cent of about 3,000 adults reared from field-collected cocoons were females. The oviposition of 47 adults was as follows:

		Eggs per adult	
YEAR	NO.	MEAN	RANGE
1937	6	115.5 ± 20.9	60 — 206
1941	14	71.3 ± 6.0	24 — 100
1942	27	52.1 ± 4.2	20 — 90

The remaining oocytes after oviposition averaged about 7 each year. The adults used for these rearings originated from a stand that had been severely defoliated for several years. The reduction in fecundity may have been related to partial starvation, but proof is lacking. Overwintering occurred in the eonymphal and pronymphal stages. The distinction between these stages is not as striking as in case of *Diprion hercyniae* (Htg.) (8). The eonymph is the first phase of the prepupa, and is recognized principally by its black ocelli. The pronymph is the last phase of the prepupa. The ocelli of this phase are whitish and opaque, and the body is somewhat shortened. Transitional phases are

Fig. 1. Moderate to severe infestations of the larch sawfly from 1933 to 1942 shown in 2-year intervals, and points where colonies of *Mesoleius tenthredinis* Morley were released and subsequently recovered in the Maritime Provinces.

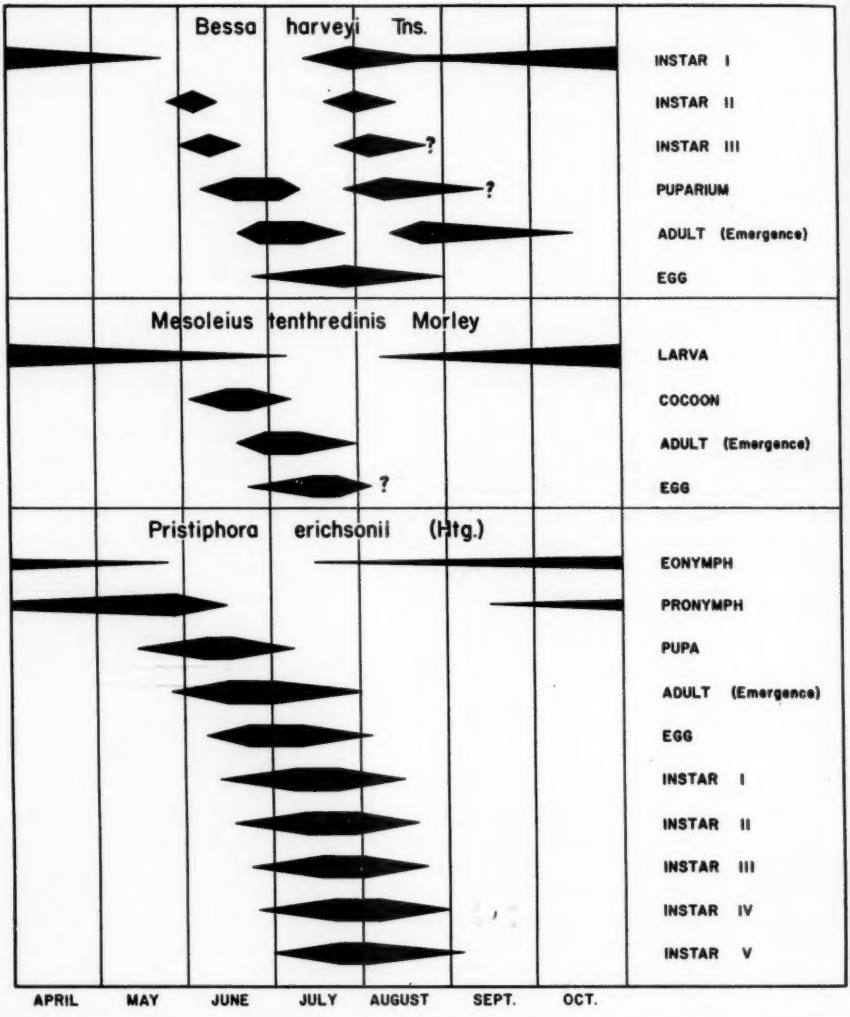

Fig. 2. Occurrence of stages of the larch sawfly and its parasites in central New Brunswick. Question marks indicate inadequate data.

sometimes encountered. The percentages that overwintered as eonymphs varied from 57 per cent to 100 per cent. The proportion of overwintering pronymphs appeared to be dependent on warm ground temperatures in the fall and light parasitism by *Mesoleius tenthredinis* Morl. Less than 2 per cent of all pronymphs dissected in the fall or spring contained larvae of this parasite, whereas up to 60 per cent parasitism of eonymphs was noted. Although the host is not actually killed until the parasite larva is in the third instar (3), it appears from dissections that the feeding of first-instar larvae tends to inhibit development of the sawfly beyond the eonymphal stage.

The seasonal distribution of the sawfly based on collections is shown in relation to that of its principal parasites (Fig. 2).

CONTROL FACTORS

Bessa harveyi Tns.

This tachinid parasite attacks the larvae, usually those in the fourth and fifth instars, but earlier instars are sometimes attacked. There was generally one and a partial second generation in central New Brunswick.

Effectiveness

Hawboldt (4) believed that the effectiveness of *B. harveyi* as a parasite of *Diprion hercyniae* (Htg.) was reduced by the sloughing of eggs and maggots, premature dying, dislodgement of maggots, and superparasitism.

The effectiveness of the parasite as a control factor of the larch sawfly was not given adequate attention, but a few observations supported Hawboldt's views. Superaparasitism was common. Dissected larvae, eonymphs, or pronymphs often contained up to three parasite maggots, but rearings showed that rarely more than one reached the adult stage. Imperfect synchronization between the emergence of second-generation adults and the presence of larch sawfly larvae (Fig. 2) would tend to reduce the effectiveness of *B. harveyi*. However, the parasite is able to attack other species of insects (4) when larval populations of the larch sawfly are low.

For some unexplained reason the degree of parasitism by *B. harveyi* was sporadic. Cocoon collections in some stands often showed high parasitism while those in adjacent stands were only lightly parasitized.

Because of the parasite's ability to pupate outside of the cocoons or larval remains, cocoon collections fail to show the true value of the parasite. Never-

TABLE I

Parasitism of Sound Cocoons of the Larch Sawfly Collected in New Brunswick and Nova Scotia from 1934 to 1942. Based on Emergence.

Year	No. collections	No. sound cocoons	Percentage parasitism by species					
			Total		*B. harveyi*		*M. tenthredinis*	
			Average	Highest	Average	Highest	Average	Highest
New Brunswick								
1934	1	1,139	25.0	25.0	25.0	25.0	0	0
1935	3	523	33.8	44.2	33.8	44.2	0	0
1936	4	524	8.8	23.0	3.6	4.5	5.2	23.0
1937	13	1,854	32.7	64.3	17.6	50.0	15.1	64.2
1938	13	1,953	28.1	85.7	10.0	46.0	18.1	67.1
1939	7	649	72.2	85.2	22.3	39.4	49.9	71.4
1940	1	264	24.2	24.2	5.3	5.3	18.9	18.9
1941	2	478	36.0	36.4	10.9	11.5	25.1	26.1
1942	1	78	67.9	67.9	23.0	23.0	44.9	44.9
Nova Scotia								
1937	2	142	8.4	8.5	8.4	8.5	0	0
1940	4	634	44.9	77.0	27.1	72.1	17.8	42.6

Note: Sound cocoons are those from which sawfly adults or parasite adults emerged. All New Brunswick cocoons from 1940 onward were taken near Oak Bay where parasitism by *Mesoleius* was generally low.

TABLE II

Parasitism of Sound Cocoons of the Larch Sawfly Collected in New Brunswick and Nova Scotia from 1938 to 1941. Based on Dissections.

Year	No. collections	No. sound cocoons	Average percentage parasitism by species			
			Total	*B. harveyi*	*M. tenthredinis*	*B. harveyi and M. tenthredinis*
New Brunswick						
1938	12	3,621	5.7	1.7	4.0	0
1939	8	3,005	21.5	4.5	17.0	0
1940	2	259	27.4	2.7	23.9	0.8
1941	4	354	47.2	11.0	32.5	3.7
Nova Scotia						
1940	7	247	51.1	30.4	16.6	4.1

Note: Majority of New Brunswock material collected in Oak Bay district where parasitism by *Mesoleius* was generally low. Parasitism was based on presence of parasite larvae.

theless, the results of rearing field-collected cocoons (Table 1) and dissecting cocoons (Table 2) show clearly that *B. harveyi* was an important factor in reducing the severity of the sawfly outbreak. The average parasitism by years ranged from 3.6 per cent to about 34 per cent, and in exceptional cases 50 per cent of the cocoons were parasitized. Cocoon dissections showed lighter parasitism but ranged from about 2 per cent to 31 per cent. A comparison of these figures with those of Hawboldt (4) shows that *B. harveyi* is much more effective as a parasite of the larch sawfly than it is as a parasite of the spruce sawfly.

Mesoleius tenthredinis Morley

This larval parasite was first introduced to Canada in 1910. Of the early liberation points, those closest to the Maritime Provinces were at Lorette, near Quebec City, and at Point Platon, 20 miles west of Quebec City (5). Colonies were released at these points in 1911. Graham (2) recovered the parasite 40 miles from the latter point in 1928 and he (3) reported additional recoveries 300 miles east of the Point Platon liberation point in 1938. Another record of interest was provided by M. L. Prebble. He reared a small colony of larch sawfly larvae collected on the upper Cascapedia River Drainage, Gaspé Peninsula, in 1934. Some were found to be parasitized by *M. tenthredinis*. The Quebec infestations of the 1930's were not contiguous with those in the Maritime Provinces, where the outbreak, as shown above, was confined to the more southerly areas. The possibility of the parasite reaching the Maritime Provinces from the infestations in the Province of Quebec is remote, and this opinion is supported by the rearing of collections in New Brunswick.

There are no early records of the occurrence of *M. tenthredinis* in the Maritime Provinces. It was not mentioned in Baird's (1) discussion of larch sawfly parasites reared in 1922 at Fredericton. Following the appearance of the last outbreak, a collection of 1,139 sound cocoons was taken at Lepreau, St. John County, N.B., in 1934, and collections totalling 523 sound cocoons were collected at Canaan River and Salisbury in 1935. None of these were parasitized by

TABLE III

Summary of Liberations of *Mesoleius tenthredinis* Morley in the Maritime Provinces Excluding Newfoundland. Records Checked by Mr. A. R. Graham, Entomology Laboratory, Belleville, Ontario.

Date	Location	Numbers liberated*
New Brunswick		
1927	Fredericton, York Co.	24
1935	New Maryland, York Co.	70
	Lepreau, St. John Co.	66
	Fredericton, 2 miles south, York Co.	96
	Canaan River, 4.8 miles east of Coles Island, Sun. Co.	600
	Waterville, 4 miles from Oromocto, Sun. Co.	280
1936	Waterville, Sun. Co.	73
1938	Frosty Hollow, West. Co.	190
	Albrights Corner, Sun. Co.	240
	Acadia Forest Experiment Station, 1½ miles west of Burpee, Sun. Co.	500
	Acadia Forest Experiment Station, 1 mile west of H.Q., Sun. Co.	282
	Acadia Forest Experiment Station, between Burpee and Noonan, Sun. Co.	150
		Total 2,571
Nova Scotia		
1937	Eureka, Pictou Co.	72
1938	Sutherland River, Pictou Co.	71
	Merigomish, Pictou Co.	55
1939	Sand River, Cumb. Co.	400
1940	Loch Lomond, west of, Rich. Co.	500
	Nuttby, Col. Co.	378
	Pomquet River, Antig. Co.	492
	Maitland Bridge, Annap. Co.	492
1942	Center Burlington, Hants Co.	300
	Elderbank, Hal. Co.	280
	Shelbourne, Shelbourne Co.	256
		Total 3,296

*Males and females.

M. tenthredinis which is fair but not conclusive evidence that the parasite was not present. The evidence justified a programme of parasite redistribution by the Division of Biological Control.

Liberations in the Maritime Provinces

The first attempt at colonizing *M. tenthredinis* in the Maritime Provinces was in 1927, when 24 adults were released in the Fredericton area. There is no record of establishment immediately following this release, and another programme of liberations was initiated in 1935. Small colonies (Table 3) were released in New Brunswick in 1935, 1936, and 1938, and in Nova Scotia from 1937 to 1942. The 1942 liberations in Nova Scotia were probably unnecessary as sawfly populations were very light at that time.

Spread

It has been shown (Table 1) that the parasite was not recovered until 1936, or one year following the first year of the second series of liberations. Any discussion on spread must be based on the assumption that the parasite did not occur in the Maritime Provinces until 1935. Parasites were recovered up to 16 miles from liberation points the second season (one year), and at locations ranging from 22 to 40 miles the third season from liberation dates. The distances between liberation points were such that it was impossible to measure spread beyond the third season.

Effectiveness

Muldrew (7) has shown that *M. tenthredinis* was an important control factor of the larch sawfly in Manitoba from 1916 to 1927. Its effectiveness in the same region in later years was greatly reduced because the eggs deposited in sawfly larvae became encapsulated by phagocytic action of the host. After 1940, effective parasitism in Manitoba rarely exceeded 5 per cent. The possibility of loss of parasite eggs from encapsulation was not recognized during the last outbreak in the Maritime Provinces. Had encapsulation been common it surely would have been detected in the several thousand sawfly larvae or prepupae that were dissected. Also, the high emergence of parasit adults (Table 1) is evidence that there were no important losses from encapsulation.

The most effective parasite during the first few years of the outbreak, until 1937 inclusive, was *B. harveyi.* This was then replaced (Table 1) by *M. tenthredinis* in importance, and the latter species continued to be the most abundant parasite until the end of the outbreak. Competition between the two species was not indicated until 1940 and 1941 (Table 2), when multiple parasitism occurred in from 1 to 4 per cent of the cocoons dissected. It has been shown by Graham (3) that in such cases of multiple parasitism, *B. harveyi* is successful over *M. tenthredinis.*

Other Parasites

Very small numbers of other insect parasites were reared from field-collected cocoons, but total parasitism of these never exceeded a fraction of 1 per cent. Species reared included the introduced eulophid, *Dahlbominus fuscipennis* (Zett.), and the ichneumonid parasites, *Eclytus ornatus* Holmgren, *Aptesis indistincta* (Provancher), and *Euceros* sp.

Mortality from Other Factors

In a collection of old and sound cocoons taken one year before the end of the outbreak (Table 4), about 48 per cent of the old cocoons were destroyed by predators, and less than 9 per cent by parasites. However, of the sound cocoons some 48 per cent were parasitized, indicating that parasites were as effective as predators during the final stages of the outbreak. About 25 per cent of the old cocoons were chewed by insect predators, possibly elaterids, and about the same proportion were destroyed by small mammals.

Of some 8,000 'apparently sound' cocoons dissected periodically for studies on development, about 22 per cent had died during the fall or following spring. About 10 per cent of nearly 2,000 old cocoons collected in one locality at the end of the outbreak (Table 4) were empty or contained dead sawflies. These records show that from 10 per cent to 22 per cent of the sawflies died in the cocoon stage from unknown causes. Some may have died from exposure to excessive water during spinning or immediately following the breaking of diapause. These are periods when resistance to immersion in water is extremely low (6).

TABLE IV

Analysis of All Cocoons Collected at Random in a Larch Stand at Oak Bay, N. B., in Fall of 1941

Class	No.	Percentage
Sound cocoons—dissected	249	100.0
Unparasitized	116	46.4
Parasitized by *M. tenthredinis*	95	38.1
Parasitized by *B. harveyi*	25	10.0
Parasitized by both species	13	0.5
Old cocoons	1,816	100.00
Containing dead sawflies	206	11.6
Containing dead parasites	3	0.1
Emergence of sawflies	574	31.6
Emergence of *M. tenthredinis* (?)	57	3.1
Emergence of *B. harveyi* (?)	97	5.3
Chewed by mammals	426	23.4
Chewed by insects	453	24.9

Discussion

The spotty effectiveness of *B. harveyi*, the apparent changing values for fecundity of the sawfly, and a trend toward an annual increase in parasitism by *M. tenthredinis* show the risk of placing control agencies in their order of importance without more intensive studies. However, the records presented herein show with reasonable certainty that *M. tenthredinis* hastened the end of the outbreak.

Muldrew (7) noted high loss of eggs of *M. tenthredinis* from encapsulation in the Prairie Provinces, and only light losses in a collection from British Columbia. The records from the Maritime Provinces show that encapsulation of parasite eggs was probably non-existent or negligible, lending support to the opinion that the condition observed by Muldrew is peculiar to the central part of the continent. However, this does not preclude the possibility that encapsulation by phagocytic action does not or will not occur elsewhere. From 1940 to 1947, 11 colonies of *M. tenthredinis* were released in Newfoundland, but severe infestations of the sawfly on the Island were reported as late as 1953. Only a few specimens of the parasite have been recovered from Newfoundland, and more information is needed on the establishment of this species and possible limitations imposed by encapsulation in this Province.

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